PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

VOL. VII.

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CONTENTS OF VOLUME VII.

PAGE

Opening Address by the President, Dr. Francis H. Thomson, Session 1868–69, . 1
On the Chemistry of Sugar Manufacture and Sugar Refining. By Dr. Wallace, F.R.S.E., F.C.S., ... 22
On the Methods and Recent Progress of Spectrum Analysis. By Mr. A. S. Herschel, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University of Glasgow, ... 38
On the Examination of the "Flame" of the Bessemer Converter. By Mr. Thomas Rowan, F.C.S., F.R.S.S.A., ... 41
On the Igniting Point of the Vapours of some Commercial Products. By Mr. W. R. Hutton, ... 49
A Chemist's View of the Sewage Question. By Mr. Edward C. C. Stanford, F.C.S., 53
On the Extension of the Coal Fields of England beneath the more recent Geological Formations. By Mr. Edward Hull, F.R.S., District Surveyor of the Geological Survey of Scotland, ... 64
The Salt Deposits at Stassfurt. By Messrs. J. H. Bald and James Mactear, . 67
On the Sun's Distance and Parallax. By Mr. St. John Vincent Day, C.E., F.R.S.E., 76
Recent Researches into the Post-tertiary Geology of Scotland. By Rev. Henry W. Crosskey, F.G.S., ... 92
On the Physical Constitution of the Sun, as revealed by the Phenomena of Solar Eclipses. By R. Grant, M.A., LL.D., F.R.S., Professor of Astronomy and Director of the Observatory in the University of Glasgow, ... 103
Minutes, ... 113
Report of Council on the State of the Society, ... 115
Report of Chemical Section, ... 126
Report of Sanitary and Social Economy Section, ... 127
Donations to the Library, ... 133
Opening Address by the President, James Bryce, M.A., LL.D., F.G.S., Session 1869-70, ... 137
Discussion on Patents for Inventions, ... 158
On the Principles affecting the Solvency of a Life Assurance Company, and the Best Means of Protecting the Public against their Violation. By Mr. James R. Macfadyen, Fellow of the Faculty of Actuaries in Scotland, ... 221
On Defects of House Construction in Glasgow as a Cause of Mortality. By Dr. W. T. Gairdner, Professor of Practice of Physic in the University of Glasgow, and Health Officer of the City, ... 245
Discussion on Defects of House Construction in Glasgow, ... 258
A Glance at some of the Vital and Social Statistics of Glasgow in 1869. By Mr. William West Watson, F.S.S., City Chamberlain, ... 262
Discussion on the Vital and Social Statistics of Glasgow, ... 286
On the Appearance and Chemical Constitution of Ancient Glass found in Tombs in the Island of Cyprus. By Mr. John M. Thomson, ... 288
On the Syenitic Rocks of Westfield, near Linlithgow, with Remarks on the Suitability of various Rocks for Harbour Works and Street Materials. By James Bryce, M.A., LL.D., F.G.S., ... 293
On China Grass, Rheea, or Ramee Fibre. By Mr. William Keddie, F.R.S.E., Secy. Phil. Soc., ... 296
Note on the Action of House Sewage on Lead Pipes. By Mr. Edward C. C. Stanford, F.C.S., ... 307
On the Estimation of Iodine and Bromine, with special reference to the Analysis of Kelp. By Mr. Robert R. Tatlock, F.R.S.E., F.C.S., ... 308
On the Chemistry of Coal-smoke. By Mr. W. R. Hutton, ... 313
On Artificial Alizarine. By Mr. J. Wallace Young, ... 316
Notes of Experiments on Artificial Alizarine. By Mr. John Christie, ... 318
Note on a Specimen of Shell Sand from the Island of Coll. By Mr. Edward C. C. Stanford, F.C.S., ... 323

	PAGE
On a Method for obtaining a Continuous Current of Air or Gas under Pressure, for Blow-pipe or other Purposes. By Mr. T. L. Patterson, F.C.S.,	323
On the Examination of Air. By Dr. R. Angus Smith, F.R.S.,	326
Minutes,	331
Report of Council on the State of the Society,	332
Report of Librarian on the State of the Library,	336
Report of Architectural Section,	343
Report of Chemical Section,	351
Report of Sanitary and Social Economy Section,	353
Opening Address by the President, James Bryce, M.A., LL.D., F.G.S., Session 1870-71,	359
Note on Stevenson's Light for Ships. By Mr. James R. Napier, F.R.S.,	386
The Farmer and the Chemist. By Mr. James Napier, Sen., F.C.S.,	387
On a Wind-direction Rain Gauge. By Mr. James R. Napier, F.R.S.,	398
On the Attractions and Repulsions due to Vibration, observed by Guthrie and Schellbach. By Professor Sir William Thomson, LL.D., F.R.S.,	401
Observations of the Recent Eclipse of the Sun in Spain. By Mr. Alexander S. Herschel, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University, Glasgow,	405
The Eclipse Observations in Sicily. By Dr. T. E. Thorpe, Professor of Chemistry in the Andersonian University, Glasgow,	413
On Helmholtz's Analysis of the Vowel Sounds. By Mr. A. S. Herschel, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University, Glasgow,	417
The Theory of the Death Rate, with Measurements of the Comparative Force of Mortality, in Glasgow and other Cities. By Mr. James R. Macfadyen, Fellow of the Faculty of Actuaries in Scotland,	425
On some Sources of Error in Volumetric Analysis. By Mr. Robert R. Tatlock, F.R.S.E., F.C.S.,	442
Note upon Scientific Education in National Elementary Schools. By Mr. Henry W. Crosskey, F.G.S.,	446
Discussion on Mr. Crosskey's Paper,	450
On the Chemical Constitution of Paraffin. By Dr. T. E. Thorpe, Professor of Chemistry in the Andersonian University, Glasgow,	454
Notes of Analyses of an Earthball and Intestinal Calculi from the Horse. By Mr. James F. Stark, F.C.S.,	456
Preliminary Notice on the Action of Chloride of Zinc upon Morphia and Papaverine, and on the Action of Nitrous Acid, Bleaching Powder, and Hydrochloric Acid upon Morphia; and some Notice of a new Opium-base. By Mr. E. L. Mayer,	459
Notes on the Cemetery of Staglieno, near Genoa. By Mr. Charles Heath Wilson,	472
On some Evidences as to the very Early Uses of Iron, and on certain Old Bits of Iron in particular. By Mr. St. John Vincent Day, C.E., F.R.S.E., &c.,	476
Minutes,	489
Report of Council on the State of the Society,	490
Report of Librarian on the State of the Library,	492
Report of Chemical Section,	501
Report of Sanitary and Social Economy Section,	503

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SIXTY-SEVENTH SESSION.

I.—*Opening Address by* DR. FRANCIS H. THOMSON, *the* PRESIDENT.

November 4, 1868.

WE have arrived, gentlemen, at an important epoch in the history of the Philosophical Society. For many years it has been quite apparent to the Council and Members that a change of some kind was absolutely necessary for its conservation; for when we look to the rapid progress of Glasgow towards the West, it could hardly be expected that men engaged in business during the day in the city would be disposed to undertake the exertion of coming so far east to attend our meetings, more especially when it is taken into consideration that the greater proportion of the members live in the West End.

This subject has been under the anxious consideration of the Society for several sessions, not only as regards our accommodation, but on account of the dangerous position of our library, caused by the extreme damp and faulty ventilation of the hall where we so long assembled.

Many schemes have been devised to enable us to carry out this most important object, and committees without number have been formed for the purpose of arriving at some definite result; but on all occasions it became painfully apparent that the funds of the Society were not in themselves in a sufficiently prosperous state to enable them to make any definite proposal; and, however willing the Council might be to adopt their suggestions, it was quite evident that nothing could be done without an appeal for pecuniary aid to the Society.

Without doubt such aid would readily have been granted by the limited number of members who at each meeting make their

appearance to support the President, and take an interest in the many valuable papers which, season after season, are brought forward. But as the average attendance, amounting to about forty, represents only one-fifth of the Society, any subscription for this purpose, although proposed and accepted by them, would not in all probability have been endorsed by the Society generally. In all the struggles of the Council, which have not been few, to inaugurate a feasible scheme for this reformatory movement, two difficulties always presented themselves,—deficiency of funds, and generally a want of sympathy. I shall not detain you by describing these various schemes, but come at once to the subject-matter of my present remarks—namely, the movement which we are this night met to inaugurate.

When the proposal, which first emanated from the Council of this Society, to convert the Corporation Buildings into halls for the different Scientific Societies and the School of Design, was originally mooted, it was looked on as utopian, and many were the anxious debates with the various committees, both connected with the Town Council and those representing the interests of science, before the scheme assumed a tangible form. Lord Provost Lumsden has personally taken a deep interest in the subject, and by his earnest and zealous assistance enabled the various committees to bring this scheme to a happy conclusion. I have much pleasure in taking this opportunity of thanking his Lordship for his hearty co-operation.

Independent of the immense value which this westward movement to secure suitable premises will be for the conservation of our valuable library, which had already begun to suffer materially from the damp in the Andersonian Hall, it will doubtless conduce much to the prosperity and activity of the Society itself. I for one look forward to the time when the Philosophical Society of Glasgow will rank as one of the most important bodies in the kingdom; and instead of attracting such a small average attendance, I trust ere long to see our members doubled, and our attendance quadrupled. Such a happy state of matters will bring about a deeper interest, not only in the meetings themselves, but in the quality and quantity of communications brought forward. The Philosophical Society of Glasgow has always, both at home and abroad, maintained a respectable reputation, and has now amongst its corresponding members some of the foremost men of the day; but its local influence has been circumscribed by causes which are now in a great measure removed; and I feel confident that the time is at hand when all who take an interest in the progress of science in Glasgow will seek to become members. In time past the Secretary and Council have had considerable difficulty in arranging

papers for the consecutive meetings, and on some occasions have been obliged to accept communications not exactly of a class to suit such a Society; but with our increased numbers, which I trust will be the result of the present movement, there will doubtless be an influx of energy and talent sufficient for any emergency. Independent of this, the Council have for some years past had under anxious consideration the propriety of submitting to the Society occasionally lectures by learned and scientific men, to which the public generally, by the permission of the Society, might have access. This scheme was followed out to a certain extent in a course of lectures delivered by Mr. John Zephaniah Bell, of London; but whether the subject was unfitted to the tastes of the Society and the public generally, or that the time had not arrived when such a movement could be thoroughly appreciated, it would be difficult to determine. Suffice it that the scheme did not succeed, and a loss resulted, which was defrayed by the members of Council. In time to come, however, it is to be hoped that, with an increased membership and ample accommodation, combined with the admirable situation of our new lecture hall, should the Society determine on following out to a certain extent such a system as that adopted by the Edinburgh Philosophical Institution, doubtless much good would result, and the operations of the Society would be much enhanced, and consequently more generally appreciated.

It is well known to you all that for two or three years past your President and Council have been unremitting in their endeavours to obtain from the Lord Provost and Town Council of Glasgow the interest upon a sum of money, amounting to nearly £1,000, being the profits, with accumulated interest, resulting from an exhibition conducted by this Society, which took place in the year 1846. This sum of money, as you are aware, was intended to be applied to the support of future exhibitions of a similar nature; but during the last eighteen years so much has been done in this way, and the public generally has been so satiated with exhibitions, that it was thought some better purpose might be served by the application of this money. In the opinion of the Council the sum clearly effeired to the Society, if not used for the above specified purpose; and after many interviews, extending over three years, with the former and present Lord Provost, it was finally arranged that the interest should be devoted to meet a portion of the increased rental appertaining to our present accommodation, on the condition that the Society should give countenance and support to a museum of patent inventions, such museum to be

contained in a hall set apart for the purpose; and also that, under certain restrictions, reading tickets, giving access for consultation to our library, should be issued by the Council of the Society, and the Lord Provost, and certain members of the Town Council equally. This arrangement seemed most satisfactory to your Council, and was last year on more than one occasion brought prominently before the Society, and finally adopted. It remains to be seen how far this concession will be taken advantage of; and it is sincerely to be hoped that the class of students for whom the privilege was intended—namely, young men having no means of either reading or consulting such books as are to be found in the Philosophical Library—may take full advantage of an arrangement so satisfactory and liberal.

When we look to the rapid progress of this great community in every department of practical science, and to the energy displayed in promoting that educational advancement, which has been shown, for example, during the last seven or eight years, by the growing feeling for Art, fostered by our annual exhibitions, it is to be hoped that the facilities granted to the rising generation, by admission to a library containing such valuable stores of information as that belonging to this Society, will do much towards the encouragement of those young men to whom we look forward as the bone and sinew of our future manufacturers and merchants. The ample accommodation afforded in our new premises will also prove a new attraction to our own members; and I feel confident that, instead of finding one or two solitary individuals frequenting the room, which, indeed, is seldom even the case, the library will be taken advantage of as a means of relaxation by a great proportion of the members. I cannot too strongly recommend to the members of the Society to avail themselves of our varied and comprehensive collection of books and periodicals; for, on comparing it with other libraries of a similar nature, I much doubt if in the kingdom there is one combining so much that is valuable in every department of science. The Society owes a deep debt of gratitude to our present Librarian, who not only has unselfishly devoted much time to the arrangement and classification of the collection, and to the completion of parts of it that were imperfect, but has, by his active communication with numerous foreign Societies, obtained their consent to exchange *Transactions* with ours, and has thus brought the library into a state of completeness and order.

In a Society constituted as this has been, and depending very much upon the energies of the officials, and those having superintendence of the management, we cannot be too grateful to a gentleman who has

for many years filled the office of Secretary, and without whose aid, given, as it has always been, energetically and disinterestedly, the Society would on many occasions have been without papers or communications. I have personally to thank him for his kindly and active co-operation during my term of office on all points connected with the business of the Society.

In seeking for a subject to form the basis of my address to you this evening, I thought it might be acceptable to review succinctly the history of the Society, and so far to give a digest of its operations from the commencement; but I find that in the session of 1857, Mr. Keddie took up this subject, and did ample justice to it. At the same time, I think it will not be out of place to make some allusion to the various distinguished men who have been members, and who have held the office of President, and who alike have been an honour to Glasgow and your Society.

In November, 1802, the Philosophical Society was constituted, and elected for its President Dr. William Meikleham, who afterwards became Professor of Natural Philosophy in the University of Glasgow. The membership at first amounted to sixty, and the meetings were held in the Assembly Rooms, but were shortly removed to the Surgeons' Hall, St. Enoch Square. Amongst the more prominent members we may mention Mr. David Hamilton, Architect of the Royal Exchange; Dr. George Birkbeck, Professor of Natural Philosophy and Chemistry in the Andersonian Institution; Mr. David Mushet; Mr. George Macintosh, of Patent Double Waterproof fabric notoriety; Mr. John Napier and Mr. Robert Napier; Mr. James Dunlop, of Clyde Iron Works; Mr. Henry Houldsworth; Mr. Charles Tennant, founder of the St. Rollox Chemical Works; Mr. Matthew Park, father of the late Mr. Patrick Park; Dr. Corkindale; Dr. Andrew Ure, author of the *Dictionary of Arts and Manufactures;* and Dr. James Watt. Subsequently the great proportion of the men who have left a name and reputation, and held prominent positions in Glasgow, became members; and when we take into consideration that such men as Dr. Thomas Thomson, Mr. Graham, the Master of the Mint, Dr. Allen Thomson, Professor Anderson, Sir William Thomson, Mr. Crum, Dr. W. J. Macquorn Rankine, and our late lamented Professor Rogers, held the President's Chair, it cannot but appear that this Society has been a means of fostering and bringing to light much that has rendered Glasgow one of the foremost cities in the kingdom. Amongst the early hard workers, we find the Messrs. Hart, Dr. Alexander Watt, Mr. Lumsden, Mr. Robert

Hastie, Mr. Andrew Liddell, who, along with Mr. Lumsden, became a member in 1818, Mr. Robert Napier, and Mr. Beaumont Neilson. We must not forget Mr. Andrew Smith, of Mauchline, and Mr. Boag, and our late lamented Chamberlain, Dr. Strang. Most, if not all, of these have now passed away, but one and all have left their mark on the city. I might go much farther in reverting to this subject; but I feel it would be treading upon what has been so well done by our respected Secretary.

The papers during all these years comprised much that is deeply interesting; and it is really refreshing to go back upon the *Transactions*, and see how much energy was displayed by the early members, not only in their essays, but in the subsequent discussions.

The Society, although keeping its place numerically for the last ten years, has not shown that activity and fruitfulness in papers which characterized its earlier history. This, as has been shown before, was much caused by the steady movement westward, and the unwillingness of men to leave their firesides and go so far east on a cold winter evening; but now that we are established in what may be called a central position, even in the newest part of our city, no such excuse can be urged; and I hope that your coming President has the prospect of presiding at meetings which will include all the best men, both in science and art, for which Glasgow is becoming famous.

Among the many questions which might be discussed in a paper of this description, there is no one more interesting to all concerned in the welfare of this country than that of cheap dwellings for the poor. Innumerable have been the schemes devised for this purpose, and much has been done by the sanitary commissions appointed all over the country, to which the question of cheap material is one of vital importance. Mr. Tall, of London, has lately patented a process which has given rise to considerable discussion as to its orginality. His object is the use of concrete, which certainly cannot be original, so far as he is concerned; for this material has been used in all times past for building purposes. In South America, walls 60 feet high have been discovered, at least 200 years old, erected on the same plan; but it can be of no consequence who the inventor was originally, for the plan is excellent, and durability simply depends on the material used. It may be fair to presume that the materials for a concrete house are economically and easily obtainable—sand and gravel, or the refuse of smelting furnaces, all being applicable. The tenants of all the houses which have been erected on Mr. Tall's principle testify to the absolute dryness of the walls, whilst the cost is about

one-half that of brickwork. One peculiarity is that little skilled labour is required. Mr. Godwin, editor of the *Builder*, published in the *Transactions of the Institute of British Architects* an essay containing valuable information on this subject, mentioning many instances where the ancients applied a mixture analogous to concrete both for foundations and walls. He goes on to state that the famous fortress of Ciudad Rodrigo was built of concrete, sand, gravel, lime, and boulders, and that the marks of the apparatus—namely, parallel boards used in moulding—were still visible. The Romans and Normans also were acquainted with a process of a similar description. Concrete building cannot well be imagined, therefore, to be a thing of yesterday; but if one were to go into the originality of all inventions having a practical application, it would be difficult to fix upon almost any process as thoroughly new. Mr. Tall has the credit of applying this process, whether original or not, to the solution of a great national question.

The immense increase of building operations, and the quantity of bricks required for all the enormous works which have been carried out for some years past, necessitating a corresponding employment of bricks and bricklayers, has almost doubled the price of the raw material; and Mr. Tall, among others, turned his mind to the alleviation of this serious difficulty. Any process which diminishes cost and gives adequate stability and bearing power, will add greatly to the facility of construction of walls, farm buildings, and labourers' cottages. If we assume the price of bricks at 20*s.* per thousand, and the wages of a good bricklayer at from 5*s.* to 6*s.* per day, one may form a pretty accurate estimate of the value of such a plan as is proposed to be adopted by Mr. Tall. The mixture is composed of Portland cement, brick rubbish, or broken stones, gravel, sea shingle, or, in fact, any durable substance. When preparing to build, a good foundation of concrete is laid in the usual way, and that being arranged, the framework or mould is commenced, which is made to screw or unscrew as required. Should a wall of 50 feet high and 200 feet long be wanted, a framework is laid down on each side of the foundation three feet thick, from side to side of the foundation, upright posts being placed resembling double rows of scaffold posts. On each side planks are screwed to the poles, made of strong, well-seasoned timber, having the clear thickness of the wall between them; cross-bars now being fastened, to keep all parallel and solid, and spaces left for the doors and windows. The framework being 10 feet high and 20 feet long, the mixture of the materials may now commence. To this end, Mr. Tall takes to every part of

Portland cement eight parts of gravel. These being mixed in the usual way by a couple of men, the next materials come to be added. These may consist of old brick rubbish, refuse of any description,—indeed, all such refuse as has been hitherto carried away as useless. When such material cannot be procured, the refuse of stone quarries, sea shingle, or any other hard substance, will do equally well. The whole mixture is now amalgamated by a bucket or two of water being added, which two additional labourers pour between the moulds. After working away until the height of the first boarding has been reached, a scaffold of some height giving additional facilities for the materials falling with a certain impetus, an even settlement takes place. No trowels are wanted, and no skilled work beyond that of the foreman who directs the erection of the framework. The strength of the wall is materially increased and consolidated by what is called punning or ramming. After this division of the structure is finished, the concrete-mixing scaffolds are carried higher up; and additional boarding being added, the wall is raised to the top. Mr. Tall states that the material sets in about an hour, and that when the framing is taken away, the surface is perfectly smooth, even, and fit for either painting, plastering, or decorating. This part of the arrangement I should very much doubt, however, as, having tried the process in a large hot-bed frame, I found the time required for setting to be greatly longer. In arranging for the ends of rafters, as the wall proceeds, what are called cores or dummy rafters are inserted, and built in with the concrete. When setting has taken place, the wedge-key of the core is taken out, and the wood extracted, leaving the rafter-bed all ready. The roof may be also formed of the same material. The rafters being adjusted, roofing boards an inch thick are nailed on, and these being covered with felt, the mixture is spread over all, 3 inches thick. The patentee further claims, that, in addition to their cheapness, these walls are much stronger than the same thickness of brickwork. Now as to cost. The patentee built some houses in Gravesend, the expense being at this rate:—Brick-kiln refuse, costing £1, 15*s.*; gravel stone, £1, 1*s.*; Portland cement, £1, 12*s.*; labour, £1, 16*s.* Out of this, and directed by a mere carpenter, were obtained sixty yards of 9-inch thick wall, at 2*s.* 6*d.* per yard; in some places, where the material could be got cheaper, the cost would be about 2*s.* As regards time, he gives one instance. On Monday, June 22d, a house was commenced in the usual way, and on Saturday, the 27th, the walls were raised 9 feet 6 inches high. This was equal to laying 14,580 bricks, and the whole was done in forty-three working hours by two labourers and a lad. The labour should be paid for at

the rate of 6*d.* for every superficial yard of a 9-inch thick wall; and by the time the houses are ready for the roof the walls will have cost in workmanship, £7, 5*s.* 9*d.*; whilst, to represent the same quantity of wall, 29,160 bricks would be used.

Mr. Tall slightly goes beyond the point when he says that no skilled labour is required; for sufficient skill should be used in order to secure that precision which is necessary for stability. Such materials, thrown together in heaps, cannot be altogether left to arrange themselves; and although great skill may not always be required, it cannot be altogether dispensed with. It will be interesting to witness the further development of Mr. Tall's principle, as it appears to possess the elements requisite to ensure soundness, solidity, strength, and durability, in whatever structure it may be applied to. Brick-building, thoroughly well carried out, combines everything that strength and finish require; but any systematic method of utilizing such mixtures, if scientifically and practically employed, will be of inestimable use in an economic point of view.

While on the subject of concrete, I should wish to say a few words upon a patented process adopted by Mr. Ransome. About the year 1844 he directed his attention to this subject, and after many experiments, in 1861, he discovered a process which is distinguished alike for its simplicity and scientific beauty. Mr. Ransome's artificial stone consists of particles of sand mixed sometimes with powdered limestone, agglomerated into a solid mass by a silicate of lime; and it is the mode by which this silicate is produced within the mass which forms the peculiarity of the process. This is carried out by mixing the particles of sand with a viscid solution, the pasty mass thus produced being pressed into the required form, and then treated with a solution of chloride of calcium. On the latter solution being applied, the silicic acid and the oxygen of the silicate of soda combine with the calcium of the chloride of calcium, and form silicate of lime; whilst the chlorine of the chloride of calcium unites with the sodium, and forms chloride of sodium, or common salt, which is subsequently removed by washing. One of the most peculiar parts of Mr. Ransome's discovery was a new mode of manufacturing the silicate of soda at a reasonable rate. This consisted in his boiling flints in a solution of caustic soda *under pressure.* The results were most astonishing. When flints are boiled in an open vessel with caustic solution, even for days, an exceedingly weak solution of silicate of soda is got; but when the process was conducted in a closed vessel, under a pressure of 60 lbs. to the square inch, even solid flints dissolved rapidly, the result being a viscid solution of silicate of soda. This in itself, in-

dependently of its application to Mr. Ransome's process, was a discovery of some importance. Mr. Ransome's works are situated at East Greenwich, and he readily procures all the material required, within a short distance. The first thing he does is to thoroughly dry the sand; and this is done by placing it in a revolving sheet-iron cylinder, through which a current of hot air is forced. As the sand requires to be very fine, it is ground into an impalpable powder, the same apparatus being used for grinding the limestone which is one of the constituents of the artificial stone. The ground sand and limestone are now mixed with the solution of silicate of soda, which is done in a machine resembling a loam mill, which has the effect of kneading the whole together into a thoroughly homogeneous mass, the process occupying about three minutes. The solid materials and soda are mixed in the proportions of about 2½ bushels of the former to 1 gallon of the latter. This, however, is varied according to circumstances. The result of this operation is a plastic substance fit to be moulded, the moulds being formed of wood and iron. The moulds are oiled, and the material is carefully inserted, so as to form a compact mass. From this material Mr. Ransome makes mantel-pieces, corbels, balustrades, and all those sorts of designs which, when carved by the hand, involve a vast expenditure of time and labour. Grindstones made of this substance are also in high repute, and form an important practical result of this manufacture. When the moulding has been finished, they are hardened by being subjected to a solution of the chloride of calcium. This in a few minutes renders the substance so hard that it can be moved and handled. The solution is forced into the substance by pressure, and the sediment afterwards removed by repeated washings. After this process the stones are immersed in a bath of the same solution, heated to about 212° by means of steam pipes, the object being the thorough expulsion of the air, and also, possibly, to increase the energy of the chemical action between the silicate and the chloride.

All articles manufactured by Mr. Ransome's process are characterized by their sharpness of outline and general beauty of finish. The colour can be varied, but naturally it is uniform. Mr. Ransome carries on an extensive business all over the world, and has thoroughly established the reputation of his products; and it is gratifying to know that he is now earning the reward of his persevering labour.

I may add that the Bombay Government, having become convinced of the advantages of this plan, have determined to erect works, and have devoted a sum of money for this purpose. It is a well-known fact that many districts in India are almost entirely unprovided with

suitable stones for building purposes; and even where stone does exist, the expense of ornamental work would be much greater. As explained before, the plant is very simple; and all the material required, with the exception of the caustic soda for preparing the silicate of soda, and the crude hydrochloric acid for the chloride of calcium, are obtainable in almost every part of India, Native labour could also be advantageously employed. Mr. Ransome has lately manufactured two screens, of a most elaborate and beautiful nature, for the new India office, each screen being 42 feet long and about 7 feet high in the centre. They are of course formed of a number of pieces, but so beautifully put together that no joints are perceptible. The colour is excellent and uniform. These are highly creditable to Mr. Ransome as specimens of his scientific process.

Much interest has lately been evinced in a new material, which in effect lessens the danger arising from blasting agents hitherto employed, more especially nitroglycerine, from whose easily explosible nature great danger to human life has always resulted, not only in its storage, but its use. Dynamite, which is the name of the new combination, consists of 75 per cent. of nitroglycerine and 25 per cent. of porous silica. Apparently a loss of power would be the result of this combination, but practically this does not seem to be the case. One difficulty of using nitroglycerine alone is, that it cannot with safety be poured into the bore-hole, as it easily explodes under pressure. The practice, therefore, is to place it in cartridges, causing considerable windage, whereas dynamite, being somewhat pasty, yields to pressure without danger, so as to fill up the sides of the bore-hole. Thus a given height of dynamite-charge in a hole contains nearly the same quantity of nitroglycerine as when used in its pure state. In testing this material, one of the experiments, quoted in a paper written by Mr. A. Nobel, the inventor, is thus described:—A block of iron 11 inches in diameter and 12 inches in height, composed of best scrap, was used; a bore-hole through the centre was made of 1 inch, and a charge of 6 ounces was put in, without securing either end with any sort of plug. This experiment was carried out at Merstham, on the 14th of July, 1868, in the presence of numerous spectators. Allowing for the bore-hole, and giving the tensile strength of the iron at 20 tons per square inch, the strain necessary to effect the rupture would be equal to 2,400 tons. Besides blasting this cylinder, one-half was hurled with such violence against a $\frac{3}{4}$th-inch boiler-plate as to fracture it. Such being its power upon iron, its efficacy upon stone blasting could not be doubted.

He goes on to state, as a proof of its safety, that a box containing 8 lbs. of dynamite, equal in power to 80 lbs. of gunpowder, was placed over a fire, where it slowly burned away; another box, with the same quantity, was hurled from 60 feet high upon a rock, and no explosion resulted from the concussion. Such results would almost ensure absolute safety from this material. At Stockholm some experiments have been lately made, putting it even to more severe tests. A weight of 200 lbs. was dropped from a height of 20 feet on a box containing dynamite, without an explosion taking place. Such tests prove its safety against concussion, in which consists the danger of nitroglycerine. The practical difficulties of conveying nitroglycerine have been very much owing to leakage, which, from its liquid state, is difficult to avoid; and especially in exporting it to hot climates, under exposure to the sun's rays, when the slightest blow will cause explosion. All this is sufficient to show the importance of making a non-explosive solid, which dynamite is fully proved to be. Besides this security, its transportation and storage are rendered almost absolutely safe. Dynamite is now generally sold in ready-made cartridges; and the workman has simply to put one into his bore-hole, and fire. Nitroglycerine, apart from its danger to the miner, proved a great boon, seeing that its explosive power was ten times greater than the same bulk of gunpowder, and therefore the number of bore-holes could be much reduced. The feeling among workmen generally being, that they would use nitroglycerine even if gunpowder could be got for nothing, so much the more will this rule hold, when in dynamite they have a combination of materials absolutely safe, and possessing the same explosive power. Dynamite resembles coarse, dark-brown sand; and, as before explained, the causes which render gunpowder and nitroglycerine so dangerous to handle have no effect upon this substance. Nitroglycerine explodes at 240° of Fahr., gun-cotton at 400°, gunpowder at 600°; but the temperature necessary to ignite dynamite must be placed somewhere between 1400° and 3280°—a common fire being only 1200°.

In my address last session I partially took up the subject of petroleum, as regards its applicability to marine and other purposes. Since then much has been written, but little more adduced, in proof of its use as an economic power; and, so far as can be ascertained, there is no application of it so simple as that now worked by Messrs. Geo. Miller and Co., Rumford Street, Glasgow, by which everything is consumed, and the utmost power obtained. Several methods for effecting the same purpose are at present in use, each inventor being

so far successful; but the most important point—that relating to its adoption in steamships—is now and has been the great object towards which all are working. Mr. Dorset, of London, has lately brought out an application which promises to be useful. The principle differs from most others in that the fuel is used in a boiling condition, its vapour being utilized under the steam boiler. For this purpose a small auxiliary boiler is placed beside the furnace proper, which is filled with creosote. A fire being started under the small boiler, when the vapour begins to rise, it is conveyed by a down pipe from the top of the boiler into the furnace, and continues the work commenced by a coal fire. Another pipe from the top of the small boiler is now carried into the furnace of the steam boiler, which it traverses, and returns to the furnace door. The pipe inside the furnace is perforated at wide distances, and through these perforations the gas issues, and is burnt beneath the steam boiler. Mr. Dorset is about to apply this process on board of a large river steamer; and it will be interesting to look forward to the results. He states that the economic advantages are very great—viz., that 120 gallons of creosote, at 1*d*. a gallon, will do the work of 2½ tons of Welsh steam coal, at 17*s*. 6*d*. per ton. Such a use for creosote would of course materially enhance its value; but under any circumstances a large margin would still be left. Messrs. Wise, Field, and Aydon have devoted much time and money to the elucidation of this question, and have patented a peculiar process for the burning of petroleum and other liquid hydrocarbons in steam boilers and other furnaces. I shall not take up your time by describing all the different apparatus by which they carry out their plans, but state so far how they propose to gain a saving. At Mr. Barnes's Chemical Factory at Hackney Wick, where their apparatus was practically tested, 15,240 lbs. of water have been evaporated in five hours in one of the boilers, by the consumption of 800 lbs. of oil, or an evaporation of 19 lbs. of water per lb. of oil. Taking into consideration that the pressure at which the boiler is worked is 28 lbs., and that the temperature of the feed-water was 667°, this performance was equivalent to the evaporation at atmospheric pressure, with a temperature of 212°, of 22 lbs. of water per lb. of oil burnt. The fuel used by them is the waste product left from coal tar, after the removal by distillation of the naphtha and light oils. It weighs about 65 lbs. per cubic foot, and has hitherto been a refuse. The great question as to what extent liquid fuels can be economically substituted for coal is very difficult of solution; in fact, from the present state of knowledge, it is impossible to give a precise answer; and in many districts where a supply could be easily obtained,

the question would be of course much more readily solved than in others where such products are not so attainable. In the case of the application of liquid fuel being applied to steam ships, and particularly to war vessels or steam yachts, the power of carrying fuel for almost an unlimited number of days' consumption would quite outweigh all question of cost. In hot climates the adoption of such fuel would add much to the comfort of stokers and others employed, as it would be comparatively easy to maintain a moderate temperature at the stoke-hole. Another important point which emerges from the experiment is, that more work can be got out of any given boiler than when worked by solid fuel.

The question of utilization of sewage, the most important in this age of progress, seems as yet to be under a cloud; for of all the many schemes propounded for the cleansing of such rivers as the Clyde, and others of a similar description, no definite economic or simple plan has yet been adopted. The nearest approach to something like a system is that for the utilization of the Thames sewage. Mr. Bazalgette, who has lately reported upon the Clyde sewage, gives some interesting notes upon this subject, under the title, "The Thames Embankment." Some facts may be selected as bearing on this subject. The first propounders of this great scheme were Sir Frederick Trench and Mr. Martin, the painter. Subsequently Mr. James Walker gave plans, as well as others; but the latter gentleman carried the day, and his scheme received the sanction of Parliament in 1862. This was for the north side of the Thames; but in 1863 the Metropolitan Board of Works got an Act for the embankment of the south side. As now constructed, the embankments on both sides of the river are entirely original, having been prepared under the auspices of the Board by their own engineer. The works for the north side were commenced in 1864, and the south in 1865. The northern embankment, as now finished, is 6,640 feet, and the cost by tender, £875,000. The southern is 5,000 by 60 feet wide, and the cost, £309,000. The whole aspect of this part of London is changed by these magnificent works, and, standing on the new bridge at Westminster, the effect is almost magical; for instead of the mud banks and ruinous-looking warehouses, with five and six tiers of coal-barges, the eye now rests upon a splendid roadway, covered with a thronging multitude, rushing hither and thither, interspersed with gaily-dressed parties drawn from all quarters of the globe. And when all is finished, there will be no undertaking in Europe, or in fact anywhere, to equal these works. The footway on the northern embank-

ment, when finished, including the roadway, will be 100 feet wide. Under this, for a considerable distance, will run the Metropolitan Railway.

In carrying out these operations 37 acres of land have been reclaimed, which it is intended to lay out in approaches, ornamental grounds, and gardens; and connected with these embankments, a system of sewers has been arranged, to remove the sewage by gravitation. It would take too much time to go into all the particulars of this vast scheme, which in effect has done much to purify the Thames; but one or two facts may be mentioned, of an interesting nature. As the sewage is carried 10 or 12 miles, gravitation cannot altogether be applied; therefore, at certain points, there are pumping stations, two for each side. On the north, the largest is the Abbey Mills, near Bow, for the north-east district of London, and is driven by an engine of 1,140 horse-power. This engine lifts the sewage of Acton, Hammersmith, Fulham, Shepherd's Bush, Kensington, Kennington, Brompton, Pimlico, Westminster, the City, &c., &c.—in fact, a space representing an area of 25 square miles—to a height of 36 feet, from the low to the high level sewers; thence it flows on by the side of the high level gravitating sewers to the northern or Barking outfall. The station itself covers 7 acres, divided by the northern level outfall sewer, which crosses diagonally, raised upon an embankment 17 feet above the surface. It is intended to make another station at Pimlico of 240 horse-power, to meet that portion of the low level sewer which is to be constructed under the embankment at Chelsea. On the south side, two stations are now existing, worked by engines respectively 500 horse-power—one at Deptford Creek, and the other at the outfall at Crossness. The utilization of a portion of this sewage has so far been carried out and successfully applied for the irrigation of a farm of 250 acres at Barking, where grass, roots, and fruit have been raised in great abundance; and the time, it is to be hoped, is not far distant when the total sewage may be so used as to go far to supply the wants of the London markets.

The evidence goes on to show that in this way sewage may be profitably employed and utilized; and a very important point has been found—namely, that the sewage carried away by the intercepting sewers and ebbing tide never returns, and consequently an incalculable benefit to London is the result. Even during all the heat of last summer the waters of the Thames have been almost entirely free from smell; and the removal of the offensive banks, saturated with sewage, is productive of a much more healthy state of matters.

"UTILIZATION OF SEWAGE.—The report of the sewage irrigation experiments made at the Lodge Farm, Barking, by the Metropolitan Sewage and Essex Reclamation Company, for the year ending August 31, has just been presented to the directors by the manager. The demand for the rye-grass, to the growth of which one-fourth of the acreage is devoted, now exceeds the supply, as its value is beginning to be appreciated. That its use in cattle-feeding is most satisfactory may be gathered from the fact that two young steers, fed exclusively on the sewage-grown grass since May 18, had increased in weight by August 7 from 6 cwt. and 7¾ cwt. to 7¼ cwt. and 9¼ cwt. respectively. Experiments of a very interesting character are detailed, illustrative of the remarkable fertilizing power of the sewage on land of the poorest and most sterile nature. And whereas it used to be one of the strong points urged against sewage irrigation, that it was good for nothing but the growth of rye-grass, the manager of the Lodge Farm is able to speak now of wheat, rye, oats, mangold, cabbage, turnips, sugar-beet, parsnips, potatoes, &c., all yielding most prolific crops from poor land receiving no other manure than the sewage. It is confidently asserted that no amount of ordinary manure could produce six or seven crops of grass a season, weighing from 6 to 12 tons each. In the case of mangold, also, the knowledge that two dressings or floodings of sewage, consisting of from 200 to 300 tons per acre each, is capable of producing a crop of from 50 to 60 tons per acre, enables a comparison to be drawn with the ordinary crop, of from 20 to 25 tons, produced with a good dressing of farm-yard dung. The crop of wheat grown last year without any manure was about 3½ qrs. to the acre; this year the yield with sewage was 5½ qrs. Not more than 1-350th of the whole of the sewage of North London is used on the Lodge Farm in a year; and as the results are so triumphantly successful, it may be hoped that the farmers of South Essex will begin to avail themselves of the means offered to them by the company for enriching their land with the valuable fertilizing stream which at present passes away in waste to the ocean."—*The Lancet.*

It has lately been a matter of some concern that the unused sewage deposit is collecting below Barking, and making quite a bank; but, as the scheme widens out, and the farmers generally take up the question of irrigation, this evil will be amended if not cured.

Messrs. Bateman and Bazalgette, of London, have lately issued a very elaborate report for the purification of the river Clyde, which is so far exhaustive of the subject, and it may be well to notice shortly their proposed scheme.

In preparing their report, a very interesting description is given of the schemes propounded by Mr. Gale, Mr. Michael Scott, Mr. Oliver, Mr. Harvey, Mr. David Napier, Mr. Laurence Hill, Mr. W. P.

Kinaird, Mr. Randolph, Mr. Hugh Maclure, and others; and although some of these gentlemen give very ingenious ideas on this great subject, none of them have been found as yet sufficiently practical to solve the question.

As the scheme of Messrs. Bateman and Bazalgette, however, is now before the committee, and may possibly be adopted, I should wish to draw your attention to a few interesting points brought out in their report as regards utilization and expenditure.

The scheme devised is thus described:—"The sewage of the higher portions of Glasgow is intercepted at an elevation of about 60 or 70 feet above ordnance datum, and by tunnelling through the intervening ridge, conveying it by gravitation alone to the coast between Irvine and Troon. An intercepting sewer at this level will remove the sewage from one-fourth of the population of the city. For the remainder, it is proposed to construct two other lines of intercepting sewers—one, the middle sewer, at an elevation of 20 feet above ordnance datum, which will take the middle zone, containing nearly one-fourth of the population; and the other, or low level sewer, at the level of ordnance datum, which represents the mean level of the tide, by which the sewage will be diverted from all the lower portions or remaining half of the city.

"The sewage from the high level districts will be concentrated near the conjunction of St. Ann with Duke Street, at Wellpark Free Church, and from thence conducted by a cast-iron syphon pipe along Hunter Street and a new street in continuation of Hunter Street, between Gallowgate and Great Hamilton Street, to Glasgow Green, across the Green and over the river a little below St. Andrew's Suspension Bridge, across the Gorbals to Cumberland Street, thence along Cumberland Street, in a direction parallel with the river, to a pumping station close by the side of the Paisley Canal, and between the canal and the Glasgow and Paisley Railway, a short distance to the west of Pollokshields. The sewage conveyed by this syphon will be discharged at a level of about 48 feet above the ordnance datum, and will there be conveyed by a circular conduit 9 feet in diameter to the coast of Ayr, about midway between Troon and Irvine."

The report goes on to explain the working of the system, and the probable results from this scheme being carried out; but as my object is more to place before you what has been going on during the last twelve months than to give any opinion on this or any other theoretical proposition, I content myself with a few statistical quotations of the probable expense and responsibility to the citizens at large.

The gross estimate of all the works of interception and conveyance to the sea, with the engine power and pumping stations required for raising the sewage to the requisite elevation, amounts by estimate to £1,089,756, of which £374,756 is due to intercepting sewers and syphons down to the pumping station at Pollokshields; £50,000 for engines, pumps, and pumping stations; and £625,000 for the main conduit between Pollokshields and the coast near Troon.

The power of the engines required for lifting the sewage is 500 horse-power, and the annual expense £3,550.

The gross outlay, including Parliamentary expenses, will be £1,253,256, the interest of which, at 4 per cent., is £50,130 per annum, which, added to the expense of pumping and administration, will give an annual expenditure of £55,000. The practical issue to the public will be an addition of 5¼*d.* per pound on the present rental; and upon the probable rental, when the works might be finished, six years hence, 4¾*d.*

Should this scheme be carried out, however, in its entirety, and the sewage used, as in London, for irrigating purposes on the sandy soil near the coast, a great reduction would be effected; and if Messrs. Bateman and Bazalgette's calculations are correct, a complete return of the whole expense might be got. Take for instance the calculation that the present volume of sewage, exclusive of rainfall, measures 35,000,000 of gallons per day, or 156,250 tons; and taking 100 tons as the quantity required for the production of 1 ton of grass, the daily produce would be 1,562 tons for 300 days. This, taking 10*s.* as the price per ton, would give something like £234,000 per annum; but considering the great rainfall, and the weaker quality of the sewage as compared with that of London, it might be well to pitch the profit at one-half; and allowing this to be divided between the promoters and the farmer, a sum of £58,000 odd would be left as the value derivable from this great scheme.

It is very gratifying to know that this subject has been so well taken up, and so much valuable information elicited; for whatever plan may ultimately be adopted, it is quite evident that Glasgow cannot remain as it is. With a population increasing in the ratio of the last twenty years, the evil is daily growing, and its cure must soon become an absolute necessity. As I have before stated, the subject is one of much difficulty; and when we have before us day by day the discrepant opinions of men equally eminent both as engineers and chemists, it is to be hoped the authorities will pause and deeply weigh all sides of the question before committing themselves to any but a sure and satisfactory solution of the question.

I might with justice refer to one or two of the plans proposed, and one of a very ingenious nature lately brought before the Town Council by Mr. William Robertson, C.E., who originally had a scheme similar to Messrs. Bateman and Bazalgette's; but his present idea is to discharge the sewage at a point below Erskine, and use the tidal waters of the estuary to flush the river. This he effects by impounding the tidal waters of the river by a wall from the south bank of the Clyde near Port-Glasgow, along the line of low-water mark upwards to the Newshot Isle, and to the east end of the isle, where the river Cart falls into the Clyde. The plan seems simple enough, and I have no doubt will meet with due consideration from the Sewage Committee. Of late we have Dr. Fergus and others advocating a totally different system for the absorption of the sewage, in the use of dry closets, and many other schemes of a similar nature; and in many parts of England various scientific men have taken up this question, and in one or two cases have partially succeeded in their object. I may mention one process which was patented and carried out at Hastings, by Mr. Rock, the mayor. About twelve years ago, Hastings was drained at a cost of £16,000, by a system adapted to the natural levels; and the sewage flowed into the sea from several outlets, causing much annoyance to the bathers visiting that locality, when the discharges took place, and fever to a great extent prevailed. Subsequently charcoal was used, which modified this. Mr. Rock's system consists of a main sewer having a fall of 5 feet 6 inches per mile, intercepting all the old drains, carrying the sewage to a tank holding a million and a half of gallons, which is the maximum accumulation of every twenty-four hours. The sewage is stowed in the tank until low water, and then discharged, the action of the tide carrying it eastward, and away from the town. The discharge from the tank is through half a mile of culverts of 4 feet with a fall of 10 feet per mile—this has cost £30,000; and as a precaution against the vapours arising from the tank, charcoal boxes are placed, through which the air passes. It is intended to carry this farther, and purify the drainage in the tank to be used as manure. Mr. Leuk has also invented a process which has been tried at Lincoln, which consists in the use of certain chemicals, the result being highly satisfactory; and it appears that the quantity used for about 4,000,600 gallons was 4 tons. Mr. Sillar has also been employed by the Tottenham Board of Health to purify the river Lee. Irrigation had been previously tried unsuccessfully, owing to the outfall being inconvenient. Precipitation by lime was also tried, but resulted in a total loss, the residue being so worthless that the farmers would not

have it. This also was tried at Leicester with the same effect. Mr. Sillar does not give the component parts of his precipitating medium, but its action was very rapid, precipitating 85 per cent. of the ammonia contained in the sewage, and all the phosphoric acid. The experiments are very interesting, but not of sufficient importance to affect such a question as the one appertaining to the Glasgow sewage; but in a small place like Lincoln, it is possible that a system of precipitation might answer, and be profitable, where, from the causes already assigned, it would be totally inapplicable to such a great scheme as the purification of the Clyde. Professor Frankland, in reporting to the Rivers Commission on the comparative merits of the two processes above mentioned, says, "That like all chemical methods hitherto invented, they fail in purifying sewage to such an extent as to render it admissible into running water." It still remains a fact, however, that no chemical process is known which even remotely approaches irrigation in its efficiency as a purifier of sewage. Both the Sillar and the lime processes remove, to a great and nearly equal extent, the suspended matters contained in sewage. The former increases the amount of dissolved solid impurity, but reduces the quantity of putrescible matter; the latter reduces both the amount of dissolved solid impurity and the quantity of putrescible organic matter, the reduction of the last being about the same as that effected by Sillar's process—namely, rather more than one-half: further, Sillar's process produces the most valuable solid manure from the sewage. Both processes, however, signally fail in removing dissolved nitrogenous organic matters from the sewage—the kind of matter which rapidly putrefies and becomes an active agent in the pollution of rivers. Both processes, indeed, actually increase the amount of organic nitrogen in solution; that is, the amount of organic nitrogen dissolved from the superadded matter of the river sewage was greater than that precipitated by the chemical re-agents added. This important deduction must lead to a modification of the favourable opinion recently expressed upon sewage operations by precipitation.

I might go on to any extent in my observations and quotations upon this interesting topic; but I think sufficient has emerged to prove the immense importance of the subject; and if my remarks have no other effect than drawing the attention of the Society to the necessity of discussing the various questions involved during the present session, my object will have been gained.

Last session the attention of the Society was drawn by Mr. Ludwig Mond to the manufacture of sulphur from alkali waste—a

subject of vast importance to Glasgow especially. It will be unnecessary for me to describe the various processes applicable to this subject which have been patented by Messrs. Schafne and Hofman, and which have largely been employed on the Continent; and which processes are based on the following re-actions:—*first,* the conversion of the insoluble compounds of calcium and sulphur in the waste into soluble compounds by the action of the oxygen of atmospheric air; *second,* the removal of these soluble compounds from the rest of the waste by lixiviation with water'; *third,* the separation of sulphur from the liquors thus obtained by muriatic acid. According to the process advocated by Mr. Mond, the oxidation of the waste is effected in the same vessels in which the waste has been originally obtained, by forcing air through the waste by means of a fan. It is then lixiviated in the same vessel; and these operations are repeated twice over without removing or touching the waste. A great saving of manual labour is thus obtained, and hours instead of days are occupied in the process. The liquors are then mixed with an equivalent quantity of muriatic acid, and heated by steam to 150° Fahr. The sulphur is now easily separated: it settles to the bottom of the vessel, is washed with water, and melted in an iron vat. The waste after the abstraction of the sulphur remains in a pure state, and furnishes a good manure for many soils and crops containing large amounts of sulphate and carbonate of calcium. One-half of the sulphur recovered by this process is in a very pure state, and surpasses all brimstone imported into this country; and consequently is not used to replace pyrites in the manufacture of soda, but in place of brimstone, which has a much higher value, and is used in very large quantities by our manufacturers. Sicily alone is said to export 300,000 tons per annum, 50,000 tons of which are sent to Great Britain. The British alkali trade, which now absorbs 400,000 tons of common salt in a year, would, by the application of this process, easily be able to supply the 50,000 tons of brimstone consumed in this country, and for which we pay Sicily £300,000 a year. This brimstone could be produced at £1 per ton, which is much less than what it costs at the mines. Too much importance cannot be placed on an invention of this description, involving as it does interests of such magnitude, and more particularly when we look at its importance in the mere matter of the manufacture of gunpowder.

In concluding my remarks, I should wish to say a few words upon the subject of Museums of Trade and Industry, more especially since, in a small way, we are called upon to institute and foster under this

roof a museum which has for its object the encouragement of inventors and exhibition of models. Although this is the ostensible object which we have pledged ourselves to foster, there is no reason why we should not have specimens exhibited of our textile manufactures, including cotton, jute, silk, &c. We might also have a classification of all the various ores that have rendered this part of Scotland so famous, as also the results accruing from these. And when we look around us in the scientific world, and find that almost every day produces some new wonder of applied science, we cannot but feel that the movement which has inaugurated and fostered such an exhibition is the beginning of what is to be hoped will ultimately lead to the institution of a museum worthy of the West of Scotland, and of this great commercial city.

II.—*On the Chemistry of Sugar Manufacture and Sugar Refining.*

By Dr. Wallace, F.R.S.E., F.C.S.

Read before the Chemical Section, December 7, 1868.

About eight years ago I had the honour of delivering a discourse to the members of the Philosophical Society of Glasgow "On some Points in the Chemistry of Sugar Refining." Since that time the sugar-refining trade of this country has undergone great changes. The Clyde houses have increased to nearly three times the amount of their former production; while in London, formerly the principal seat of the manufacture, many of the refineries have altogether ceased working, while others are doing but little business. The Greenock sugar is now sold in nearly every considerable town in Great Britain and Ireland, and it is a fact that raw sugar has been purchased in London and in Liverpool, refined in Greenock, and sent back again to the place it came from. The English ports, especially London and Liverpool, possess great advantages so far as the purchase of the raw material is concerned; but Greenock has other circumstances in her favour that more than counterbalance these advantages. In Greenock we have cheap ground, cheap labour, cheap coals, and water not only very moderate in price, but of a quality remarkably well adapted for refining purposes, while the re-burning of charcoal is not regarded as a nuisance. The same favourable circumstances exist also, although

to a less extent, in Glasgow; and it appears highly probable that but for the want of a good raw-sugar market, the refining trade would soon be in great measure confined to the Clyde. There cannot be a doubt that the Greenock refiners have exhibited during the last ten or twelve years extraordinary enterprise, and have taken the lead in the introduction of improvements, both mechanical and chemical; while, on the other hand, they have rejected various innovations which have turned out miserable failures. The Greenock refiners have, however, been poorly repaid for their energy, perseverance, and skill; the extraordinary competition between the different firms has made it difficult to find an outlet for the produce, while the French and Belgian system of duties on the raw sugar, and drawback, as it is called, upon the refined when exported, operate against them in common with all other British refiners. I shall refer to this subject by and by; but in the meantime shall merely state briefly that the Governments referred to offer a premium to their refiners to export their produce—they charge a duty on the raw sugar, and on the refined being exported give a drawback amounting to considerably more than the duty that was paid. A direct result of this unfair competition is that loaf sugar cannot now be made profitably in this country, and that branch of the trade may almost be said to have ceased.

In the production of crushed sugar an immense impetus has been given by the introduction of the centrifugal machine for draining the syrup away from the crystals; not the least of the advantages being the extremely rapid return of the sugar in a marketable form, it being possible to have the refined product ready for sending out in thirty-six hours from the time the raw sugar was "blown up." The whole system of refining has undergone a great change: a much larger quantity of charcoal is now used than formerly, and it is much more frequently renewed, and there is now very little of extremely low sorts manufactured, the production being mostly confined to two kinds, whites and yellows. Another innovation is boiling down to "a jelly," as it is technically called—that is, without graining in the pan; and the pans are so much improved by very wide necks, to permit the free escape of the steam, extensive heating surface, and great condensing power, that a panful of the largest size may be boiled down in two or three hours and at a temperature ranging from 50° to 55° Cent. (122° to 131° Fahr.) Another alteration of the system—I can scarcely call it an improvement, although I suppose it is now necessary, in order to make ends meet—is the practice of "in and in" working, whereby no syrup is ever turned out, but the whole produce leaves

the house as it came in, in the form of sugar. In former times—that is, six or eight years ago—the raw sugar being dissolved and decolourized, yielded a liquor which, on boiling down, gave a crop of crystals of white, or nearly white, sugar called "lumps," and a syrup called technically "green syrup." This green syrup was again boiled down, and gave a second crop of crystals called "pieces," and a syrup which was either sold as "golden syrup," or boiled down again to obtain a further quantity of sugar. In any case the ultimate result was that the accumulated salts and other impurities of the raw sugar, so far as they were not extracted by the charcoal, were got rid of in the golden syrup. At the present time the Greenock houses, as a rule, turn out no syrup; in other words, the impurities referred to are carried out of the sugar-house in the yellows, these being purposely made with a very small grain, so as to carry a large quantity of syrup. These are, in few words, some of the more salient features of the present system as distinguished from that existing only a very few years ago; but there are also important improvements in many particulars, such as in the purchase of raw sugars, the chemical examination from time to time of the charcoal as well as the various products of the refinery, and an intelligent scientific supervision of the whole process, which contrasts strikingly with the rule-of-thumb system of former times.

In the preparation of the raw material, considerable changes have occurred. The most notable of these in regard to cane sugar is the system of Mr. Fryer, of Manchester, by which the cane juice is boiled down, or rather evaporated, very rapidly by exposing it to heated air in a very thin stream running over an inclined plane, by means of which a result is obtained which becomes solid on cooling, and is imported into this country under the name of "concrete." In the beet sugar manufacture the "carbonatation" process has been followed out to a considerable extent, and, in fact, is becoming universal. This consists in the addition to the juice of a rather large quantity of lime, which is afterwards separated by a current of carbonic gas. A peculiar vacuum pan is employed for the evaporation of the weak syrups, three pans being arranged in one connection, the steam of the first being made to heat the second, and the steam of the second the third. This is called the "triple effet," and is now very generally employed.

Having briefly introduced the subject, I shall now proceed to consider, in greater detail, the various branches into which it may be divided; premising, however, that for the sake of making the whole matter connected, and, to some extent, complete, it will be necessary

to mix up with a little that is new a great deal with which many of you are already very well acquainted.

Varieties of Sugar.—Of the many varieties of sugar known to chemists, two only, so far as I am aware, are concerned in sugar refining, viz., cane sugar and fruit sugar, but we may also take into our catalogue that kind known as grape or starch sugar. The three varieties contain respectively the following quantities of carbon, hydrogen, and oxygen:—

Cane sugar, or sucrose, ...	$C_{12}H_{22}O_{11}$.
Fruit sugar, or fructose, ...	$C_{12}H_{24}O_{12}$.
Grape or starch sugar, or glucose, . . .	$C_{12}H_{24}O_{12},2H_2O$.

Fruit sugar and glucose were formerly confounded together, but they have been conclusively shown to be quite distinct, as much so as cane sugar and fruit sugar; but fruit sugar is clearly intermediate between sucrose and glucose, which last is the ultimate result of the action of acids, heat, and ferments upon all other forms of sugar, as well as upon the other members of the amylaceous group. In all these changes there is simply the assimilation of the elements of water. Very weak acids, with the aid of heat, effect the conversion of cane sugar, first into fruit, and then into grape sugar; an elevated temperature alone, in presence of water, accomplishes the same transformations, but less rapidly. The following experiments, made with a solution of pure sugar in distilled water, illustrate well the danger of keeping syrups at a high temperature for a lengthened period of time. In the first experiment a quantity of the syrup was heated to about 90° Cent. (194° Fahr.), until a large proportion of the sugar crystallized out; more water was then added, and the evaporation and solution repeated several times. A thick syrup was at last obtained, which refused to give any crystals when kept for weeks over oil of vitriol. Analysis showed the mixture to contain cane and fruit sugar in the proportion of 1 of the former to 14 of the latter. In the next experiment the syrup was kept for several months in one of the floors of a sugar house, the temperature of which varied from 32° to 38° Cent. (90° to 100° Fahr.), water being from time to time added. A thick, almost semi-solid, syrup was thus obtained, which did not show the slightest appearance of crystals even under the microscope. It contained 1 part of cane sugar to 10 of fruit sugar. The syrup was left exposed in the same vessel for some time afterwards without undergoing any apparent change, when suddenly the whole was transformed into a soft solid mass, consisting of microscopic, but distinct, crystals of glucose. Weak acids give rise to the formation of grape sugar; but

this change does not appear to begin until all the cane sugar has first been converted into fructose. I have never observed crystals of glucose in any of the ordinary products of the sugar house. Heavy syrups and treacle contain generally minute crystals, but the microscope shows these to be cane sugar, the angles being as sharply defined as in sugar candy. Fruit sugar does not crystallize at all, but forms, on evaporation, a tenacious semi-solid mass. This description, however, rather belongs to a mixture of fruit sugar with a small proportion of cane sugar, for as soon as the latter disappears the formation of grape sugar commences. Grape sugar crystallizes without difficulty from a tolerably strong solution, provided the latter has not been exposed to too high a temperature.

The natural distribution of the varieties of sugar may be disposed of in a few words. When the saccharine juices are acid, as in grapes and other common fruits, the variety of sugar present is fructose, which changes when the fruits are dried and kept for some time, especially if the skins are ruptured; so that in dried fruits, such as figs and raisins, hard granular masses of glucose are frequently met with; but when the juices are either alkaline or neutral, cane sugar is the variety of saccharine matter present. We have cases in which, in the same plant, at different times, or in different parts of the plant, we have an acid sap containing fruit sugar, and an alkaline sap containing cane sugar. No doubt is entertained by chemists that the sugars play a very important part in the nutrition of plants, and in the vegetable organism there seems to be a perfect facility in the change from cane to fruit sugar or *vice versâ*. Out of the laboratory of the plant, however, it is very different; we can readily change cane to fruit or grape sugar, but the backward operation is one that defies our powers. We have lately seen many wonderful transformations of organic bodies and the artificial formation of compounds hitherto formed only by natural processes, but we have not yet been able to change fructose or glucose into cane sugar, and I, for one, do not expect that it ever will be done.

Cane sugar crystallizes readily in four-sided prisms with rhomboidal bases, but the crystals have often a cubical appearance, and sometimes, by truncation, they assume the aspect of six-sided prisms. The crystals are always sharp and well-defined, even when produced from the most impure syrups. Cane sugar is distinguished from all other substances by its intensely sweet taste, which, when the sugar is pure, is unaccompanied by any kind of flavour. As the sensation of sweetness depends very much on the rapidity of solution, it follows that fine-grained sugar, which dissolves rapidly in the mouth, appears

sweeter than large crystals, which dissolve slowly, and hence the absurd popular notion that one kind of sugar can be sweeter than another, both being equally pure. Cane sugar is devoid of odour and colour. It is highly soluble in water, which takes up, at the comparatively low temperature of 9° Cent. (48° Fahr.), about an equal weight. With increase of temperature the power of solution is very much augmented, and at the boiling point of the liquid the capacity of water for dissolving sugar is almost unlimited. At the degree of heat at which syrups are boiled down in the vacuum pan (49° to 54° Cent., or 120° to 130° Fahr.), water does not by any means possess this power of unlimited solution, and the sugar readily crystallizes out if the syrup is not too much loaded with impurities.

Fruit sugar is uncrystallizable, but forms, when dried in vacuo at the ordinary temperature of the air, a gummy, semi-solid mass. It possesses a left-handed rotative power on polarized light, from which circumstance it has received the rather clumsy names of "lævulose" and "inverted sugar." I have never found this variety of saccharine matter, as produced artificially, in a pure state, but always more or less mixed with cane sugar. It exists abundantly in golden syrup, molasses, treacle, also in honey, especially when new. Cane sugar refuses to crystallize from a syrup which contains rather more than an equal weight of this variety, and I have found that a syrup which is saturated and which contains less than 8 of cane to 10 of fruit sugar, is absolutely undrainable at any temperature. Here, then, is a serious evil in sugar-refining—every pound of fruit sugar destroys the crystallizing power of nearly as much cane sugar. With regard to the sweetening power of fruit sugar, I cannot give any precise information, as I neglected to ascertain this point when I had an opportunity of examining a nearly pure specimen. Ordinary golden syrup, which contains about 40 per cent. fruit sugar, and 30 to 35 per cent. cane sugar, appears fully sweeter than a solution of pure cane sugar, but it has a certain flavour, and contains alkaline salts which prevent a proper estimate of the sweetness being made. It is stated, however, to be superior to grape sugar, but inferior to cane sugar, in sweetening power.

Fruit sugar is more soluble in alcohol than cane sugar, which, indeed, is practically insoluble in absolute alcohol; and this liquid has been proposed for washing crystals of cane sugar for the purpose of freeing them from adhering syrup, without materially affecting the crystals themselves. The experiment succeeds admirably on the small scale, and has long been used on the Continent for testing raw sugars, but there are certain difficulties in applying it in actual practice, say upon 50 to 100 tons per day of material. It would be

hopeless to use it unless duty-free, on account of its expense, and, besides, it is difficult to obtain a cheap alcohol of such purity that it would not communicate a flavour to the sugar, while methylated spirit is quite inapplicable. Still, I believe that alcohol might be introduced into the sugar refineries of this country for washing raw sugar if it could be had duty-free. Of course the sugar would be refined in the usual way afterwards, but the product would be much superior to that obtained by the ordinary process of refining.

Much has been written about the dialysis of impure syrups, and when Professor Graham's paper on dialysis first appeared I tried the process upon golden syrup, but without a satisfactory result. The process has never been applied on the large scale in this country, so far as I know, but it has been adopted successfully in some of the Continental refineries with beet syrups containing a large quantity of chloride and nitrate of potassium, chloride of sodium, and other alkaline salts, and the efforts of those who have tried it have rather been to separate those salts than to dissociate the cane from the fruit sugar, of which beet juice contains only traces. I expected that fruit sugar would have acted as a colloid, and would have refused to pass in any considerable quantity through the dialysing septum, but in this I was disappointed. If time permits, I will briefly describe Dubrunfaut's apparatus, called the "Osmogene," used for dialysing beet molasses.

Grape sugar, otherwise called starch sugar, or inverted sugar, or lævulose, never occurs in any of the products of the sugar manufacture, so far, at least, as my observations have gone. It crystallizes in fibrous masses or tufts radiating from a centre, presenting a very beautiful appearance when examined with a lens. The crystals are said to be cubical, but usually they are minute and indistinct. It is less soluble than cane sugar, requiring about an equal weight of cold water for solution. It is less sweet than cane sugar in the proportion of 2½ to 1. Fruit sugar soon changes to glucose if no cane sugar is present. As I have already stated, we frequently find granular lumps of glucose in raisins and other dried fruits, the skins of which have been ruptured. The whiteness and viscousness of old honey is due to the presence of crystals of glucose, while new honey is a clear transparent syrup. I have seen jelly prepared from the juice of currants, and other acid fruits, and loaf sugar, in which, by too long-continued boiling, all the cane sugar had been changed, become opaque and semi-solid from the same cause. This phenomenon must not be confounded with the much more common one of cane sugar forming a hard crisp crust upon the surface of the jelly.

Glucose is largely manufactured in France from potato starch, and more lately in America from Indian corn, and is extensively used by brewers, distillers, and confectioners; but it is not likely to come into use as a sweetening agent, unless it be to adulterate the cheaper kinds of refined sugar; and as these are now sold at about 3*d.* a pound, there does not appear to be much chance of extensive fraud being practised in this direction.

I have already referred to the action of weak acids in inverting cane sugar, if I may be allowed to use the expression, and may here add that it is of the utmost importance in sugar refining to prevent the occurrence of even the slightest trace of acid, which not only changes the cane sugar more or less into the uncrystallizable variety, but enables the liquors to dissolve iron from animal charcoal or from iron tanks or cisterns, besides other impurities. In this way Mr. Beane's process for treating animal charcoal with hydrochloric acid gas, although otherwise all that can be desired, has entirely failed.

Alkalies act but little upon cane sugar (I mean when very dilute), but upon fruit sugar they act energetically, producing glucic acid, and subsequently other compounds of a brown colour. Hence it is that while with beet juice, which contains at most only traces of fruit sugar, a considerable excess of lime may safely be used in clarifying; the same treatment upon cane juice or a solution of common raw sugar produces, on boiling, a dark-brown colour.

The action of ferments on sugars, so far as these are concerned in the process of sugar refining, next claims our attention. In my paper of eight years ago this subject occupied a large space, but now I may dismiss it in a few words. The fact is that the duration of the whole process of refining is now so very short that there is little time for fermentation.

In the sugar-house two kinds of fermentation are recognized. The first of these affects chiefly strong or comparatively strong liquors, and communicates to them a peculiar viscidity and ropiness, and the property often seen in treacle and occasionally in golden syrup, of drawing out to a thread of extreme tenuity. This is technically called "smear," from the circumstance that such viscous liquors will never drain away from crystals with which they may be mixed. Frequently sugar-houses have been entirely stopped from the occurrence of smear, which, once introduced, seems to spread like an epidemic. It appears to be the same kind of action that is so troublesome in the West Indies in making rum from molasses, which is called the viscous fermentation, and which is now prevented by mixing a considerable quantity of sulphuric acid with the liquor while undergoing the alcoholic fermen-

tation. Smear is always the result of filthiness, and may be prevented with certainty by keeping everything about the sugar-house clean, and fumigating with sulphurous gas. In my paper already referred to, in which this subject is treated of at considerable length, I have ascribed the occurrence and propagation of smear to the action of microscopic vegetable organisms, which I invariably found to be present in smeary liquors; but smear is now a thing of the past, and I will not waste time in referring to it further.

The other kind of fermentation, however, which I shall call the lactic, demands our earnest attention, for no sugar-house is absolutely free from it, although in those that have placed themselves under competent chemical direction it is reduced to a trifling amount, and gives little or no trouble. The lactic fermentation occurs only in weak liquors, especially in those below 5° Baumé; it is most active at a temperature ranging from 38° to 49° (100° to 120° Fahr.), and it is produced most energetically by the oxidizing action of animal charcoal. This subject has been minutely described in my paper on "Animal Charcoal," published only a few months since,* but I shall briefly summarize the matter. When sugar liquor is run hot into a cistern filled with animal charcoal, and drawn off again at a comparatively high temperature, little or no fermentation occurs; but when the process is ended, and the char, impregnated with vegetable albumen and various impurities extracted from the liquor, is washed with water containing free oxygen, the char is soon cooled down to the temperature most favourable to the lactic fermentation, and the washings come away sour and putrid, and more or less loaded with lactate of calcium and other salts, the lime being derived from the calcic carbonate contained in the charcoal, besides a distinct quantity of iron. The weaker the washing water, it is generally the more acid, until at last the washings contain more calcic salts than sugar. It is customary to use the weak char washings for dissolving fresh sugar, but this is a most pernicious system, as, amongst other evils, it introduces iron into the crushed sugar, together with an offensive odour. These evils, as described in my paper on "Charcoal," may be prevented by keeping up the char cisterns to a pretty high temperature, and washing with water kept constantly boiling. The char washings also, if not immediately boiled down, should be kept up to near the boiling point by means of steam pipes.

Having thus described the two varieties of sugar concerned in sugar refining, I shall now allude briefly to the—

* Vide *Proceedings of the Philosophical Society of Glasgow*, vol. iv., p. 377; also abstract in *Chemical News*, vol. xvii., p. 249.

MANUFACTURE OF CANE SUGAR.

A tolerably complete description of the principles and practice of this industry will be found in various books of reference, such as Knapp's *Technology*, Muspratt's *Dictionary*, or Ure's *Dictionary of Arts* (new edition), and I shall only refer to a few points. The sugar cane contains about 16 per cent. of sugar and 70 per cent. of water, together with about ·3 per cent. of soluble salts, making altogether about 86 per cent. of juice, of which three-fourths are expressed in the cane-crushing mill, provided it is a good one, and one-fourth is left in the megass or crushed canes. One would fancy that such a great loss as one-fourth of the whole produce of the growth of the cane would make the planters careful to save any further loss or deterioration of the product, yet until very recently the process of treating the cane juice after expression has been exceedingly crude and wasteful. The juice, at about 10° Baumé, is mixed as soon as possible with a certain amount of lime, called temper lime, and heated in a vessel called the clarifier. A scum rises to the surface (consisting of vegetable albumen and other matters), and, after settling, the clear liquor is run off to the first of a series of evaporating pans in which, gradually transferred to a pan nearer the source of heat than the last, it is boiled down to such a consistence that on cooling it forms a good crop of crystals. The mixture is afterwards placed in hogsheads or casks perforated with holes into which reeds are inserted, and the mother liquor, called molasses, is allowed to drain away; but the sugar is never fully drained, and consequently loses considerably on the voyage to this country. The process has many other disadvantages: the high temperature of the pans, or "teaches," as they are called, especially the last of the series, in which the juice is boiled down to the strength necessary for forming crystals, gives rise to the formation of a large quantity of fruit sugar and of coloured products, the subsequent removal of which, by animal charcoal, adds much to the expense of refining. And, again, in most factories sufficient care is not taken to prevent fermentation, hence acids are formed which, in the boiling down, favour the formation of fruit sugar, which in ordinary West India sugar, such as is used for refining purposes, generally amounts to from 4 to 6 per cent. The use of sulphurous acid, sodic sulphite, and calcic bisulphite, has been attended with most favourable results in our West India colonies, preventing fermentation very completely, and also improving the colour of the product. Of the three forms in which sulphurous acid may be used, that of the gas is, I believe, the best, but the bisulphite of calcium is somewhat easier of

application, and answers the purpose perfectly well. The use of sulphurous acid is to prevent fermentation in the juice when weak—after it has acquired a tolerably high density there is comparatively little tendency to ferment. The employment of various forms of evaporators in which steam is the heating power has also greatly improved the character of our colonial produce; but unfortunately our sliding scale of duties offers, as it were, a premium to planters to produce a dark-coloured sugar, for the finer the colour the higher is the duty. The duties charged upon sugar entering the ports of the United Kingdom are as follows, the various numbers referring to arbitrary standards; formerly the Dutch standards were in use, of which No. 6 is an extremely low sugar—in fact, almost black—and No. 20 is pure white:—

Refined Sugar, ...	12*s.*	per cwt.
No. 1 (above No. 15, D.S.), ...	11*s.* 3*d.*	„
„ 2 (from 11 to 15, D.S.), ...	10*s.* 6*d.*	„
„ 3 („ 9 to 11, D.S.), ...	9*s.* 7*d.*	„
„ 4 (below 9, D.S.), ...	8*s.*	„
Molasses, ...	3*s.* 6*d.*	„

The evaporators referred to are all constructed upon the principle of taking up a quantity of the liquor in a hot state and exposing it to the air; in one form of it we have a reel of pipes connected by drums or discs at each end, with steam passing through, and as the reel revolves one-half the pipes are in the liquor and the other half in the air, with a thin coating of the liquor upon them; in another form of the apparatus a series of flat hollow discs, kept filled with steam, are fitted to a hollow axis by which the discs are revolved constantly, one-half in the liquor, the other half in the air. Vacuum pans are now largely used in the colonies, but the product obtained with them —at least, the first crop of sugar—is more suitable for direct consumption than for refining. In the ordinary mode of boiling down, only one crop of sugar is obtained, but when a vacuum pan is used, and the process is otherwise carefully conducted, two crops may be had. Thus in Mauritius there is prepared, first a fine hard-grained sugar largely used in England for domestic purposes (in Scotland raw sugar is only used for refining), and next what is called "syrup-Mauritius sugar," used by refiners. The molasses in this case are not very good, at least if I may judge from the rum that is imported from Mauritius. It has been attempted to make refined sugar in the colonies direct from the juice, but without much success. The scarcity of skilled labour, the dearness of fuel, and in many cases the want of a copious supply of pure water, have all operated against the realization

of this scheme, and practically the idea has been abandoned. The next best thing would appear to be to boil down the whole juice in such a manner as not to destroy it, and then bring it to this country to be refined; and this is the principle of Mr. Alfred Fryer's concretor. This is an apparatus which has for its object the boiling down the juice, as soon as it is expressed, with great rapidity, so as to prevent fermentation, and in such a manner as not to affect the colour by too high a temperature. The juice is poured on to one end of a nearly flat iron table with ridges placed across it, so that the liquor travels from side to side about sixty times before it reaches the bottom of the inclined plane, the length of which is about 48 feet, and the breadth 6 feet. A furnace is placed at that end of the machine where the liquor enters, and the flame travels down to the lower end where the waste gases are utilized in heating a current of air which is afterwards passed, first through the inside of a cylinder placed upon its side and revolving so as to keep a fresh portion of juice always exposed to the heated air, the temperature of which is about 350° Fahr., and then in the opposite direction over the surface of the evaporating liquor, the air being impelled by a fan. The flow of juice at the upper end is regulated so that the evaporated liquor escapes at the end at 25° or 30° Baumé, and after passing through the cylinder, forms, on cooling, a tolerably hard dry cake, containing only 6 to 8 per cent. of water. This product is concrete. It has been said that cane juice contains no fruit sugar, but if this is the case with the canes as they are growing, it certainly does not hold in the case of the expressed juice, for the concrete, according to numerous analyses I have made, contains from 4 to 12 per cent. of fruit sugar, averaging at least 7, and the inferior lots are, therefore, unsuitable for refining on the Greenock system of putting out no syrup.* Mr. Fryer's process is an admirable and a most valuable one; only I think it is, in the case of bad juice, carried too far. If the juice, when bad in quality, were allowed to leave the apparatus with 15 to 20 per cent. of water in it, and the cooled product were drained or put through centrifugal machines, an article would be obtained which would contain a very moderate proportion of uncrystallizable sugar and very suitable for refining, while the molasses would only amount to about 15 or 20 per cent. of the total produce. The advantages of the concrete are—great rapidity of production; prevention of the formation of fruit sugar and coloured products; the almost entire absence of loss from drainage during the

* The imports of concrete from Antigua this year have contained an average of only 4·2 per cent. fruit sugar, according to Mr. Fryer, but the produce of some of the other islands has not been so good.

sugar in this country; the obtaining the entire product of the juice without loss, and the lessening to a large extent of the labour formerly required.

In the East Indies a considerable quantity of sugar is made from a kind of palm tree, and from another tree which yields what is called jaggery sugar; but it is not necessary for me to describe the processes. Maple sugar is made in Canada, but only in small quantities, and the consumption of it is chiefly confined to the locality where it is made.

I cannot, however, avoid referring at some length to the manufacture of sugar from beet-root, an industry of recent origin, brought into existence by what may be called accidental circumstances, but one that has arrived in a marvellously short time at a state of high perfection. Our refiners have adopted many valuable improvements from their Continental neighbours, and although as refiners only they may consider themselves inferior to none in the world, they cannot afford to remain in ignorance of any improvements introduced into the fabrication of beet sugar.

When the beets are brought to the *fabrique* with their heads and tails cut off, they are at once sent up by an elevator to a washing machine, which is a cylinder into which the beets enter at one end and come out sufficiently washed at the other. They are next brought in contact with a rasping machine, consisting of a cylinder about 18 inches in diameter with small teeth upon its circumference, revolving at about 1,200 revolutions per minute, by which they are reduced, with extreme rapidity, to a very fine pulp. The pulp, as quickly as it is produced, is placed in small bags, holding probably about 30 lbs. each, and these are subjected, between stout sheet-iron plates, to the action of a screw press, and afterwards to that of another press, where, by hydraulic power, the juice is very thoroughly squeezed out, leaving the pulp almost dry. The juice is passed immediately to a *mont-jus*, in which to every hectolitre of juice is added 10 litres of milk of lime of 25° Baumé (about 1·2 sp. gr., or 40° Twaddell). When full, the mont-jus is closed and steam injected, by which the mixture is sent up to a higher flat, and into a vessel where the first carbonatation is effected. In this vessel the liquor is heated, but not boiled, and carbonic anhydride, made by decomposing limestone by heat, is injected by a pipe placed at the bottom of the vessel and pierced with holes. The passage of the gas occupies about twenty minutes; the liquor is examined from time to time, and when the calcic carbonate formed appears grainy and settles readily, the process is finished. The liquor, at first of a red colour and muddy, is now nearly colourless and pretty clear. The whole contents of the

carbonatation vessel are run into a cistern, and the calcic carbonate and impurities carried with it allowed to settle down, after which the clear liquor is transferred to a mont-jus, in which it is mixed with 1 litre of milk of lime of 25° Baumé to every hectolitre of juice, and this is followed by a second treatment with carbonic gas. The liquor, after settling, is filtered through animal charcoal, after which it passes, at a strength of 3° to 4° Baumé, into the peculiar apparatus used for evaporation, called the *triple effet*, or triple effect, although the translation does not convey the exact meaning of the original. It is, in fact, a series of three vacuum pans, all connected together; the weak liquor, as it is evaporated in the first, being after a time transferred to the second, and the contents of the second to the third, from which at last it is drawn off at a gravity of 20° to 25° Baumé. The pans are upright cylinders, about 10 feet high and about 4 or 5 feet wide, and the construction is similar to that of an upright multitubular boiler. Steam (sometimes waste steam from a high-pressure engine) is admitted to the first of the three pans, which is boiled at a vacuum of about 7 inches; the steam from this pan (that is, the steam from the sugar liquor) heats the second one, which is boiled at about 14 inches of vacuum, and the steam from this heats the third, which is boiled at as complete a vacuum as can be obtained, say 27 to 28 inches. The saving of fuel effected by the use of this combination, as compared with that of a single vacuum pan, is about a third—that is to say, 2 tons of fuel with this system evaporate as much water as three tons with the ordinary vacuum pan. It is not adapted, however, to the strong liquors of a refinery, or the rapid boiling then required, so that I do not see how we can profit by this experience of our ingenious French neighbours, unless, perhaps, it might be in boiling down char washings.

From the *triple effet* the evaporated juice is elevated by a mont-jus to a cistern, where it is heated to boiling, then passed through animal charcoal, and lastly boiled down to a grain in a vacuum pan of the usual construction. An almost perfectly white sugar is obtained, and the syrup is boiled over again, and so on three, four, or five times, the product becoming gradually darker in colour and more contaminated with alkaline salts and organic impurities. The last crop of sugar is allowed to stand in cisterns for several weeks, in order to crystallize, as the salts retard considerably the crystallization of the sugar. The beet sugar that comes to this country for refining purposes is, I believe, the third or fourth crop, and contains from $1\frac{1}{2}$ to 4 per cent. of alkaline salts, there being sometimes a very considerable quantity of nitrates present. The syrup drained from the last

crop, or beet-root molasses, is a very impure substance. It has a gravity of about 1·4, and, according to my own analyses, contains about 50 per cent. cane sugar, about 0·5 per cent. fruit sugar, about 13 per cent. of extractive, gummy, and other vegetable matters, and 13 per cent. of salts, chiefly of potassium, the remainder being water. Until a year or two since this molasses, being unfit for food, was fermented, and a coarse kind of spirit made from it, while the residue in the still was boiled down and calcined to obtain salts of potassium, the most valuable of these being thé carbonate. But by a most beautiful adaptation of Graham's dialyser, by Dubrunfaut, the salts are to a large extent removed, after which the greater part of the sugar can be crystallized out. The apparatus is called the Osmogene, and consists of about fifty cells, separated by sheets of parchment-paper, laid flat and connected at the edges all round, the space between each pair of sheets being fully half an inch. Each sheet is supported by a cross piece of wood and a network of twine. The whole arrangement is about 4 feet long and 3 feet high. By a peculiar arrangement of connection the syrup admitted from below passes through every second division, while water admitted above also passes through every second space, and at last flows off below at a strength of 1° to 2° Baumé, or, say, 1° to 2½° Twaddell. Owing to the high diffusive power of the salts as compared with that of sugar, the former readily pass through, together with only a comparatively small proportion of the sugar, which may be saved, as before, by fermentation. This will no doubt appear to many too delicate a process for a work on the large scale, but experience has proved that it works well, and that six such machines are sufficient for a *fabrique* working daily 250,000 kilogrammes, or about 250 tons of beets. The same inventor has also another process intended for the same object—that of separating the sugar from the alkaline salts. The sugar is thrown down as a sucrate of barium, by the addition of sulphide of barium, and the precipitate, after being washed, is decomposed by a current of sulphurous gas, which forms the insoluble sulphite of barium, and sets free the sugar. Traces of baryta in the liquor are afterwards got rid of by a current of carbonic gas or a little solution of alum. This process, like that of Scoffern for the refining of sugar, introduces a poisonous substance, but there is no difficulty whatever of getting rid of it completely.

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Dr. Wallace here intimated that he had only been able to overtake about half of his subject, and hoped on an early occasion to devote an entire evening to the chemistry of sugar refining. An animated discussion followed, chiefly relating to concrete and to the beet-root industry. A gentleman connected with the sugar trade in Greenock stated that the growth of the sugar beet in this country was about to be commenced under the auspices of Mr. Duncan, sugar refiner in London, and formerly of Greenock.*

* For the continuation of the subject, vide *Journal of the Chemical Society*, vol. vii., p. 100.

III.—*On the Methods and Recent Progress of Spectrum Analysis.* By Mr. A. S. Herschel, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University of Glasgow.

Read before the Chemical Section, March 1, 1869.

The portion of the solar spectrum which is most generally visible under all circumstances of the atmosphere, and in which the bright line spectra of the metals obtained with the spark of a Rhumkorff coil are most distinctly seen, is that contained between the Fraunhofer's dark lines A and G, at the least and most refrangible ends of the spectrum as it appears in Kirchhoff's maps, the last of which was published in 1863. The air-spectrum, between the poles of an induction coil, was subsequently employed by Mr. Huggins in his researches on the spectra of some of the chemical elements, published in the *Philosophical Transactions* for 1864, as a standard of comparison with the bright-line spectra of the metals produced together with it in the induction spark. The superior heat of the voltaic arc being found to produce more vivid spectra of the elements, and to exhibit lines in the violet portion not usually seen with the induction coil, a blue line in the spectrum of lithium was thus first discovered by Professor Tyndall in addition to the orange line which Dr. Bunsen had detected in it by the application of a Rhumkorff coil. To extend Kirchhoff's scale of reference to the wider range of artificial spectra, the labour of completing the map of the solar spectrum by delineating the violet portion, and comparing it with the voltaic spectra of the chemical elements, was carried out by Professor Angström with the assistance of Mr. R. Thalén, at Upsala; and the work was published in the *Proceedings of the Stockholm Academy* for February, 1865. Confining their attention chiefly to the iron spectrum produced by two stout iron poles of a Bunsen battery of fifty cells, the spectrum of this metal was found to contain so many bright lines, especially in the violet portion, that, in addition to seventy-three iron lines found by Kirchhoff and Hoffman to have counterparts in the dark solar lines between A and G, about 220 were added to the number in that space, and 170 more between G and H, making the whole number of iron coincidences about 460, to which, it was believed, one or two hundred might have been added, had not the short summer and deficient sunlight in the high northern latitude put an end to their comparisons.

With a greater battery power and an equally extensive trial of other chemical elements, whose vapours appear to be present in the sun, the probability was suggested that the innumerable black lines of the solar spectrum, which still remain outstanding when those of iron are subtracted, may at length be accounted for without assuming the existence of chemical elements in the solar atmosphere with which we are unacquainted on the earth. The solar character of four new sodium lines, which were first pointed out, and their coincidence with Fraunhofer's lines was suspected by Mr. Huggins in his researches, was confirmed; while the agreement of a prominent dark line about half-way between G and H, designated *h* by the authors, with a fourth line of the spectrum of incandescent hydrogen was established, proving, with the correspondences of the other lines at C, F, and G, the existence of that element in the sun. The metal manganese was placed for the first time on the list of solar elements, and fifty new correspondences of calcium lines were noted in addition to those already previously observed by Kirchhoff. In a Swedish work on spectrum analysis,* published in the following year, Mr. Thalén has compiled a very complete chart of spectra of the chemical elements, referred, like the above-mentioned chart of Mr. Huggins, to the bright lines of incandescent air, and continued, as far as they could be traced, to the violet end of the spectrum. It will easily be perceived that the addition of so many characteristic bright lines in the spectra of the chemical elements, by the use of the voltaic arc, by giving greater certainty to the results, facilitates, in a corresponding degree, the practical applications of the spectroscope. Moreover, in order to establish a natural scale for the uniform representation of artificial spectra, Professor Angström last year published a Normal Atlas of the Solar Spectrum,† in which the wave lengths of the Fraunhofer lines are employed to delineate them, so that the spaces between them represent the differences of their wave lengths enlarged to ten million times their natural dimensions. The most refrangible Fraunhofer line, H, occupies a point at 3,933 millimètres, and the least refrangible line, *a*, a point at 7,185 millimètres on the map, which are ten million times the wave lengths of those lines; and the entire map, consisting of six plates of two lines each, is 11 feet 6 inches in length. The violet end of the spectrum in this projection is more compressed, and the red end more expanded, than corresponds to

* *Spectralanalys, Exposé och Historik; Med en Spektrelkarta.* Af Rob. Thalén, Upsala, Edquist & Berglund, 1866.

† *Spectre Normal du Soleil,* par A. J. Angström, Upsal, 1868. The plates are drawn by Mr. Thalén.

their natural appearance. If, however, in place of the wave lengths the number of impulses in a second, or their scale of pitch, as in musical notes, were employed for projecting the Fraunhofer's lines, a nearly natural representation of the prismatic spectrum would be obtained; and the above objection to the use of the normal scale, which may not, however, be of very great theoretical importance, might yet practically be removed with some advantage. A series of elementary bright line spectra, showing their counterparts among the solar lines, is laid down in the margin of the map, with the following numbers of the corresponding lines of each, in their correct places on the scale, viz.:—Iron, 450; titanium, 116; calcium, 68; manganese, 63; nickel, 35; cobalt, 19; chromium, 18; barium, 10; sodium, 9;* magnesium, 7; copper, 7; zinc (blue lines), 2; aluminium (violet lines), 2; hydrogen, 4. By a series of remarkable coincidences, if not of absolute agreements, twenty-four lines of titanium, twenty-one of calcium, and four lines of manganese, are represented in the map as corresponding exactly in their positions with iron lines. A similar agreement between a double line of nitrogen and a double line of oxygen was observed by Mr. Huggins in the spectrum of incandescent air;† but as the correspondence appeared, on closer examination, not to be absolutely perfect, it was shown to be probably an accidental, although certainly a most curious coincidence. In Angström's Normal Atlas the air spectrum is placed on a parallel line with the solar spectrum, extending throughout its length, so as to include the lines of the elementary spectra between them. The comparison of the latter with either of the two standard scales is accordingly made a matter of easy reference. At the end of the atlas is placed a chart of the atmospheric dark lines and spaces of the solar spectrum, a large number of which are now known to owe their presence in it to the absorption produced by aqueous vapour in the earth's atmosphere. This cloudy group of lines is well characterized by Mr. Thalén as forming a faint ground, from which the true solar lines of the inverted metallic spectra, tolerably deep black and well-defined, stand out, as if seen in perspective, in strong relief. In place of the four glass prisms used by Mr. Kirchhoff in his researches, a single bisulphide of carbon prism, with a refracting angle of 60°, a collimator, and an astronomical telescope magnifying forty times, were found to

* Three of the new lines of the sodium spectrum are double, like the familiar D line, and the fourth is a narrow nebulous line, making the total number of nine separate bright lines in the spectrum of this vapour.

† "Researches on the Spectra of some of the Chemical Elements." *Philosophical Transactions* for 1864, part ii.

be a sufficiently powerful apparatus to distinguish all the lines shown in Kirchhoff's maps, and to add to them the numerous lines recorded in the above-mentioned drawings by Mr. Thalén. From the foregoing description of their recent publications, it will be seen that the operations of the Swedish observers continue to afford fresh data of practical value to spectral analysis, as well as some very important contributions of a novel and interesting kind to spectroscopic science.

IV.—*On the Examination of the "Flame" of the Bessemer Converter.* By MR. THOMAS ROWAN, F.C.S., F.R.S.S.A.

Read before the Chemical Section, March 29, 1869.

THE Bessemer process for the manufacture of steel is now among the most important of our metallurgical operations, the chemical changes which it exhibits being as interesting as the mechanical appliances designed for the working of the process are ingenious. On account of its comparatively recent introduction among established industries, it affords an ample field for scientific investigation; and there is no feature of the process which is at once so interesting and important as that of the flame which issues from the "converting vessel."

The success of a "blow" undoubtedly depends on the accuracy and completeness of many details; but of them all, the most important is to know and catch that moment in the existence of the flame when the carbon in the iron has yielded its last trace to the oxygen of the air.

If a charge is "over-blown"—that is, if it be subjected to the action of the air for too long a period; or if it be "under-blown"—that is, if the admission of air is stopped before the proper chemical action has been completed—the steel will be found to be defective in proportion to its unskilful treatment.

The flame issuing from the converter is the index of these changes which the molten mass of metal is undergoing during the process; but the exact moment of decarburization is often, from a variety of causes, difficult to determine.

It is for these reasons that the examination of the flame forms the point of attraction of the process; and I have thought it might not

application, and answers the purpose perfectly well. The use of sulphurous acid is to prevent fermentation in the juice when weak—after it has acquired a tolerably high density there is comparatively little tendency to ferment. The employment of various forms of evaporators in which steam is the heating power has also greatly improved the character of our colonial produce; but unfortunately our sliding scale of duties offers, as it were, a premium to planters to produce a dark-coloured sugar, for the finer the colour the higher is the duty. The duties charged upon sugar entering the ports of the United Kingdom are as follows, the various numbers referring to arbitrary standards; formerly the Dutch standards were in use, of which No. 6 is an extremely low sugar—in fact, almost black—and No. 20 is pure white:—

Refined Sugar, ...	12*s.*	per cwt.
No. 1 (above No. 15, D.S.), ...	11*s.* 3*d.*	„
„ 2 (from 11 to 15, D.S.), ...	10*s.* 6*d.*	„
„ 3 („ 9 to 11, D.S.), ...	9*s.* 7*d.*	„
„ 4 (below 9, D.S.), ...	8*s.*	„
Molasses, ...	3*s.* 6*d.*	„

The evaporators referred to are all constructed upon the principle of taking up a quantity of the liquor in a hot state and exposing it to the air; in one form of it we have a reel of pipes connected by drums or discs at each end, with steam passing through, and as the reel revolves one-half the pipes are in the liquor and the other half in the air, with a thin coating of the liquor upon them; in another form of the apparatus a series of flat hollow discs, kept filled with steam, are fitted to a hollow axis by which the discs are revolved constantly, one-half in the liquor, the other half in the air. Vacuum pans are now largely used in the colonies, but the product obtained with them—at least, the first crop of sugar—is more suitable for direct consumption than for refining. In the ordinary mode of boiling down, only one crop of sugar is obtained, but when a vacuum pan is used, and the process is otherwise carefully conducted, two crops may be had. Thus in Mauritius there is prepared, first a fine hard-grained sugar largely used in England for domestic purposes (in Scotland raw sugar is only used for refining), and next what is called "syrup-Mauritius sugar," used by refiners. The molasses in this case are not very good, at least if I may judge from the rum that is imported from Mauritius. It has been attempted to make refined sugar in the colonies direct from the juice, but without much success. The scarcity of skilled labour, the dearness of fuel, and in many cases the want of a copious supply of pure water, have all operated against the realization

of this scheme, and practically the idea has been abandoned. The next best thing would appear to be to boil down the whole juice in such a manner as not to destroy it, and then bring it to this country to be refined; and this is the principle of Mr. Alfred Fryer's concretor. This is an apparatus which has for its object the boiling down the juice, as soon as it is expressed, with great rapidity, so as to prevent fermentation, and in such a manner as not to affect the colour by too high a temperature. The juice is poured on to one end of a nearly flat iron table with ridges placed across it, so that the liquor travels from side to side about sixty times before it reaches the bottom of the inclined plane, the length of which is about 48 feet, and the breadth 6 feet. A furnace is placed at that end of the machine where the liquor enters, and the flame travels down to the lower end where the waste gases are utilized in heating a current of air which is afterwards passed, first through the inside of a cylinder placed upon its side and revolving so as to keep a fresh portion of juice always exposed to the heated air, the temperature of which is about 350° Fahr., and then in the opposite direction over the surface of the evaporating liquor, the air being impelled by a fan. The flow of juice at the upper end is regulated so that the evaporated liquor escapes at the end at 25° or 30° Baumé, and after passing through the cylinder, forms, on cooling, a tolerably hard dry cake, containing only 6 to 8 per cent. of water. This product is concrete. It has been said that cane juice contains no fruit sugar, but if this is the case with the canes as they are growing, it certainly does not hold in the case of the expressed juice, for the concrete, according to numerous analyses I have made, contains from 4 to 12 per cent. of fruit sugar, averaging at least 7, and the inferior lots are, therefore, unsuitable for refining on the Greenock system of putting out no syrup.* Mr. Fryer's process is an admirable and a most valuable one; only I think it is, in the case of bad juice, carried too far. If the juice, when bad in quality, were allowed to leave the apparatus with 15 to 20 per cent. of water in it, and the cooled product were drained or put through centrifugal machines, an article would be obtained which would contain a very moderate proportion of uncrystallizable sugar and very suitable for refining, while the molasses would only amount to about 15 or 20 per cent. of the total produce. The advantages of the concrete are—great rapidity of production; prevention of the formation of fruit sugar and coloured products; the almost entire absence of loss from drainage during the

* The imports of concrete from Antigua this year have contained an average of only 4·2 per cent. fruit sugar, according to Mr. Fryer, but the produce of some of the other islands has not been so good.

voyage to this country; the obtaining the entire product of the juice without loss; and the lessening to a large extent of the labour formerly required.

In the East Indies a considerable quantity of sugar is made from a kind of palm tree, and from another tree which yields what is called jaggary sugar; but it is not necessary for me to describe the processes. Maple sugar is made in Canada, but only in small quantities, and the consumption of it is chiefly confined to the locality where it is made.

I cannot, however, avoid referring at some length to the manufacture of sugar from beet-root, an industry of recent origin, brought into existence by what may be called accidental circumstances, but one that has arrived in a marvellously short time to a state of high perfection. Our refiners have adopted many valuable improvements from their Continental neighbours, and although as refiners only they may consider themselves inferior to none in the world, they cannot afford to remain in ignorance of any improvements introduced into the fabrication of beet sugar.

When the beets are brought to the *fabrique* with their heads and tails cut off, they are at once sent up by an elevator to a washing machine, which is a cylinder into which the beets enter at one end and come out sufficiently washed at the other. They are next brought in contact with a rasping machine, consisting of a cylinder about 18 inches in diameter with small teeth upon its circumference, revolving at about 1,200 revolutions per minute, by which they are reduced, with extreme rapidity, to a very fine pulp. The pulp, as quickly as it is produced, is placed in small bags, holding probably about 30 lbs. each, and these are subjected, between stout sheet-iron plates, to the action of a screw press, and afterwards to that of another press, where, by hydraulic power, the juice is very thoroughly squeezed out, leaving the pulp almost dry. The juice is passed immediately to a *mont-jus*, in which to every hectolitre of juice is added 10 litres of milk of lime of 25° Baumé (about 1·2 sp. gr., or 40° Twaddell). When full, the mont-jus is closed and steam injected, by which the mixture is sent up to a higher flat, and into a vessel where the first carbonatation is effected. In this vessel the liquor is heated, but not boiled, and carbonic anhydride, made by decomposing limestone by heat, is injected by a pipe placed at the bottom of the vessel and pierced with holes. The passage of the gas occupies about twenty minutes; the liquor is examined from time to time, and when the calcic carbonate formed appears grainy and settles readily, the process is finished. The liquor, at first of a red colour and muddy, is now nearly colourless and pretty clear. The whole contents of the

carbonatation vessel are run into a cistern, and the calcic carbonate and impurities carried with it allowed to settle down, after which the clear liquor is transferred to a mont-jus, in which it is mixed with 1 litre of milk of lime of 25° Baumé to every hectolitre of juice, and this is followed by a second treatment with carbonic gas. The liquor, after settling, is filtered through animal charcoal, after which it passes, at a strength of 3° to 4° Baumé, into the peculiar apparatus used for evaporation, called the *triple effet*, or triple effect, although the translation does not convey the exact meaning of the original. It is, in fact, a series of three vacuum pans, all connected together; the weak liquor, as it is evaporated in the first, being after a time transferred to the second, and the contents of the second to the third, from which at last it is drawn off at a gravity of 20° to 25° Baumé. The pans are upright cylinders, about 10 feet high and about 4 or 5 feet wide, and the construction is similar to that of an upright multitubular boiler. Steam (sometimes waste steam from a high-pressure engine) is admitted to the first of the three pans, which is boiled at a vacuum of about 7 inches; the steam from this pan (that is, the steam from the sugar liquor) heats the second one, which is boiled at about 14 inches of vacuum, and the steam from this heats the third, which is boiled at as complete a vacuum as can be obtained, say 27 to 28 inches. The saving of fuel effected by the use of this combination, as compared with that of a single vacuum pan, is about a third—that is to say, 2 tons of fuel with this system evaporate as much water as three tons with the ordinary vacuum pan. It is not adapted, however, to the strong liquors of a refinery, or the rapid boiling then required, so that I do not see how we can profit by this experience of our ingenious French neighbours, unless, perhaps, it might be in boiling down char washings.

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III.—*On the Methods and Recent Progress of Spectrum Analysis.* By Mr. A. S. Herschel, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University of Glasgow.

Read before the Chemical Section, March 1, 1869.

The portion of the solar spectrum which is most generally visible under all circumstances of the atmosphere, and in which the bright line spectra of the metals obtained with the spark of a Rhumkorff coil are most distinctly seen, is that contained between the Fraunhofer's dark lines A and G, at the least and most refrangible ends of the spectrum as it appears in Kirchhoff's maps, the last of which was published in 1863. The air-spectrum, between the poles of an induction coil, was subsequently employed by Mr. Huggins in his researches on the spectra of some of the chemical elements, published in the *Philosophical Transactions* for 1864, as a standard of comparison with the bright-line spectra of the metals produced together with it in the induction spark. The superior heat of the voltaic arc being found to produce more vivid spectra of the elements, and to exhibit lines in the violet portion not usually seen with the induction coil, a blue line in the spectrum of lithium was thus first discovered by Professor Tyndall in addition to the orange line which Dr. Bunsen had detected in it by the application of a Rhumkorff coil. To extend Kirchhoff's scale of reference to the wider range of artificial spectra, the labour of completing the map of the solar spectrum by delineating the violet portion, and comparing it with the voltaic spectra of the chemical elements, was carried out by Professor Angström with the assistance of Mr. R. Thalén, at Upsala; and the work was published in the *Proceedings of the Stockholm Academy* for February, 1865. Confining their attention chiefly to the iron spectrum produced by two stout iron poles of a Bunsen battery of fifty cells, the spectrum of this metal was found to contain so many bright lines, especially in the violet portion, that, in addition to seventy-three iron lines found by Kirchhoff and Hoffman to have counterparts in the dark solar lines between A and G, about 220 were added to the number in that space, and 170 more between G and H, making the whole number of iron coincidences about 460, to which, it was believed, one or two hundred might have been added, had not the short summer and deficient sunlight in the high northern latitude put an end to their comparisons.

With a greater battery power and an equally extensive trial of other chemical elements, whose vapours appear to be present in the sun, the probability was suggested that the innumerable black lines of the solar spectrum, which still remain outstanding when those of iron are subtracted, may at length be accounted for without assuming the existence of chemical elements in the solar atmosphere with which we are unacquainted on the earth. The solar character of four new sodium lines, which were first pointed out, and their coincidence with Fraunhofer's lines was suspected by Mr. Huggins in his researches, was confirmed; while the agreement of a prominent dark line about half-way between G and H, designated *h* by the authors, with a fourth line of the spectrum of incandescent hydrogen was established, proving, with the correspondences of the other lines at C, F, and G, the existence of that element in the sun. The metal manganese was placed for the first time on the list of solar elements, and fifty new correspondences of calcium lines were noted in addition to those already previously observed by Kirchhoff. In a Swedish work on spectrum analysis,* published in the following year, Mr. Thalén has compiled a very complete chart of spectra of the chemical elements, referred, like the above-mentioned chart of Mr. Huggins, to the bright lines of incandescent air, and continued, as far as they could be traced, to the violet end of the spectrum. It will easily be perceived that the addition of so many characteristic bright lines in the spectra of the chemical elements, by the use of the voltaic arc, by giving greater certainty to the results, facilitates, in a corresponding degree, the practical applications of the spectroscope. Moreover, in order to establish a natural scale for the uniform representation of artificial spectra, Professor Angström last year published a Normal Atlas of the Solar Spectrum,† in which the wave lengths of the Fraunhofer lines are employed to delineate them, so that the spaces between them represent the differences of their wave lengths enlarged to ten million times their natural dimensions. The most refrangible Fraunhofer line, H, occupies a point at 3,933 millimètres, and the least refrangible line, *a*, a point at 7,185 millimètres on the map, which are ten million times the wave lengths of those lines; and the entire map, consisting of six plates of two lines each, is 11 feet 6 inches in length. The violet end of the spectrum in this projection is more compressed, and the red end more expanded, than corresponds to

* *Spectralanalys, Exposé och Historik; Med en Spektrelkarta.* Af Rob. Thalén, Upsala, Edquist & Berglund, 1866.

† *Spectre Normal du Soleil*, par A. J. Angström, Upsal, 1868. The plates are drawn by Mr. Thalén.

their natural appearance. If, however, in place of the wave lengths the number of impulses in a second, or their scale of pitch, as in musical notes, were employed for projecting the Fraunhofer's lines, a nearly natural representation of the prismatic spectrum would be obtained; and the above objection to the use of the normal scale, which may not, however, be of very great theoretical importance, might yet practically be removed with some advantage. A series of elementary bright line spectra, showing their counterparts among the solar lines, is laid down in the margin of the map, with the following numbers of the corresponding lines of each, in their correct places on the scale, viz.:—Iron, 450; titanium, 116; calcium, 68; manganese, 63; nickel, 35; cobalt, 19; chromium, 18; barium, 10; sodium, 9;* magnesium, 7; copper, 7; zinc (blue lines), 2; aluminium (violet lines), 2; hydrogen, 4. By a series of remarkable coincidences, if not of absolute agreements, twenty-four lines of titanium, twenty-one of calcium, and four lines of manganese, are represented in the map as corresponding exactly in their positions with iron lines. A similar agreement between a double line of nitrogen and a double line of oxygen was observed by Mr. Huggins in the spectrum of incandescent air;† but as the correspondence appeared, on closer examination, not to be absolutely perfect, it was shown to be probably an accidental, although certainly a most curious coincidence. In Angström's Normal Atlas the air spectrum is placed on a parallel line with the solar spectrum, extending throughout its length, so as to include the lines of the elementary spectra between them. The comparison of the latter with either of the two standard scales is accordingly made a matter of easy reference. At the end of the atlas is placed a chart of the atmospheric dark lines and spaces of the solar spectrum, a large number of which are now known to owe their presence in it to the absorption produced by aqueous vapour in the earth's atmosphere. This cloudy group of lines is well characterized by Mr. Thalén as forming a faint ground, from which the true solar lines of the inverted metallic spectra, tolerably deep black and well-defined, stand out, as if seen in perspective, in strong relief. In place of the four glass prisms used by Mr. Kirchhoff in his researches, a single bisulphide of carbon prism, with a refracting angle of 60°, a collimator, and an astronomical telescope magnifying forty times, were found to

* Three of the new lines of the sodium spectrum are double, like the familiar D line, and the fourth is a narrow nebulous line, making the total number of nine separate bright lines in the spectrum of this vapour.

† "Researches on the Spectra of some of the Chemical Elements." *Philosophical Transactions* for 1864, part ii.

be a sufficiently powerful apparatus to distinguish all the lines shown in Kirchhoff's maps, and to add to them the numerous lines recorded in the above-mentioned drawings by Mr. Thalén. From the foregoing description of their recent publications, it will be seen that the operations of the Swedish observers continue to afford fresh data of practical value to spectral analysis, as well as some very important contributions of a novel and interesting kind to spectroscopic science.

IV.—*On the Examination of the "Flame" of the Bessemer Converter.* BY MR. THOMAS ROWAN, F.C.S., F.R.S.S.A.

Read before the Chemical Section, March 29, 1869.

THE Bessemer process for the manufacture of steel is now among the most important of our metallurgical operations, the chemical changes which it exhibits being as interesting as the mechanical appliances designed for the working of the process are ingenious. On account of its comparatively recent introduction among established industries, it affords an ample field for scientific investigation; and there is no feature of the process which is at once so interesting and important as that of the flame which issues from the "converting vessel."

The success of a "blow" undoubtedly depends on the accuracy and completeness of many details; but of them all, the most important is to know and catch that moment in the existence of the flame when the carbon in the iron has yielded its last trace to the oxygen of the air.

If a charge is "over-blown"—that is, if it be subjected to the action of the air for too long a period; or if it be "under-blown"—that is, if the admission of air is stopped before the proper chemical action has been completed—the steel will be found to be defective in proportion to its unskilful treatment.

The flame issuing from the converter is the index of these changes which the molten mass of metal is undergoing during the process; but the exact moment of decarburization is often, from a variety of causes, difficult to determine.

It is for these reasons that the examination of the flame forms the point of attraction of the process; and I have thought it might not

be uninteresting to the members of this Society to describe to them the general appearance which this flame presents to the eye, and some experiments which my brother has made with the spectroscope and with coloured glasses, for the purpose of more readily determining that critical period or "change" in the flame which I have spoken of. The success of these latter experiments has enabled him to attain the object for which they were commenced; and he has designed an instrument, which I shall describe hereafter, by which the "change" in the flame is more easily determined.

First.—The General Appearance of the Flame to the Eye.

When the vessel is first turned up, a shower of brilliant sparks is ejected, owing to the force of the blast reaching first a thin layer of metal as the vessel slowly swings round to the vertical position.

From 0° to three or four minutes,

When the full head of metal is over the blast, at first, for three or four minutes, there is scarcely any flame, only a current of very hot gases and very numerous sparks.

From three or four to five or six minutes,

Gradually a small pointed flame appears in the centre of the sparks, and this quickly increases in size, without gaining much brilliancy for two or three minutes.

From five or six to nine or ten minutes,

During the next period of four or five minutes the flame is very unsteady, both in size and in position, and its oscillations are accompanied by hollow sounds as of reports or explosions in the interior of the converter.

From nine or ten to eleven or twelve minutes,

Streaks or flashes of brighter flame now shoot up through this comparatively non-luminous flame, and within one or two minutes give place to a continuous stream of dense and brilliant fire, which rushes far up the chimney and illuminates the entire building, often casting the shadows of the cranes, &c., against the windows through which the sun is shining.

From eleven or twelve to fifteen or sixteen minutes,

This flame gradually becomes thinner and more transparent, without losing any of its brilliancy, during the six or seven minutes of the "blow" which generally remain, until it suddenly (preceded, however, by a few hollow and peculiar sounds from the interior of the vessel) loses its brilliancy and much of its size, and drops down within about half a minute to nearly the size it had reached at about five minutes

of the blow; this flame, however, being both more dense and more luminous than the flame at that earlier period.

Any of the stages described may, from a variety of causes, be prolonged, or an insufficiency of blast, however caused, may lengthen the entire period of the "blow" for several minutes; but the above is a fair average blow with the best English hematite pig iron. If inferior irons are used, the flame at the change is more or less enveloped in a dense white smoke, and the change is accompanied by violent pulsations or "coughings" of the entire flame, which, under these circumstances, has often a yellowish red colour to the eye; all this making it often very difficult, if not impossible, to detect the change. Nervousness or biliousness, by variously affecting the sight of the observer, may also render him unable *with certainty* to determine the precise moment when he ought to "turn down"; and there is a marked difference in the facility of observation noticeable between a blow taking place in daylight and one at night.

Second.—The Appearance of the Flame as examined by means of the Spectroscope.

It was important first to note if any of the lines belonging to the Bessemer flame were to be found in the flame given off from the coke-fire used to heat up the converter. Several examinations were made. The result of these was, that besides the invariable yellow bright line, the red line and the two bright green lines next the yellow were occasionally to be seen. Owing, however, to the want of brilliancy in this flame, the spectrum which it gave was very faint, and at times almost invisible.

On first turning up the vessel, and for about four minutes thereafter, the spectroscope showed only a continuous band of light with the colours rather hazy, and so much blended with one another as to make it impossible to mark the junctions of the different fields.

In from four to six minutes flashes of the yellow line became visible (corresponding to the appearance of tongues of a bright flame shooting up in the centre of the dull red one issuing from the mouth of the converter), and in one or two minutes after its first appearance this line became quite steady, and did not disappear even at the end of the "blow." Simultaneous with the steadying of the yellow line, the red, yellow, and green fields became clear and well-defined bands of bright colour.

In half a minute to a minute later a bright green line appeared

near the yellow, following which, in scarcely ever more than half a minute, a red line appeared equi-distant from the yellow (of course on the opposite side). These two generally became steady together (having first appeared in intermittent flashes); in about half a minute after both were visible. With the steadying of these two lines, at once a second green line (bright, and about the centre of the green field) became visible, wavering a little at first. About a quarter of a minute served generally to steady it, although sometimes it was a minute and a half from the appearance of the first green line till the second green line, with the red, became steady.

In one to two minutes a third green line nearer the blue field came into view, and in about one minute was steady. When the red appeared with the first green line, the second and third green lines generally appeared together; but when the red appeared with the second green line, the third green was accompanied by a blue bright line near the green field. In about ten minutes after turning up the converter the flame attained its maximum size and intensity of light, when a second and a third bright line became visible in the blue field. Very often these were only intermittent and very faint; but with "hot metal" and a bright flame they were pretty steady and distinct, and were broader than those in the yellow, green, and red fields.

Occasionally, for about two or three minutes before the close of the "blow," a bright line was seen in the purple field, pretty far to the right of the spectrum. Sometimes this only flashed brightly, but on a few occasions it was clearly seen, though faint.

With a very bright flame several dark lines were seen; but for want of definiteness it was impossible to say whether they were not due to the contrast afforded by the brilliancy of the bright ones beside which they appeared. A narrow dark line was seen on each side of the red line, and a broad dark band dividing the yellow from the green. Then one between each green line, and two in the blue field between the three blue lines. But these were only seen with an exceptionally bright flame, and therefore are not of much importance.

All the bright lines visible remained steady for several minutes before the close of the "blow," affording an excellent opportunity for their examination; but at the last all (with the exception of the yellow) faded in less than thirty seconds. The purple line disappeared first (whenever it happened to be visible), then the three blue lines in the inverted order of their appearance, then the third green, after which the second, then the red, and last of all the first green, when the blast was shut off.

The green and the red lines, from their distinctness, afforded the

best point for a determination of the process; and these were so constant that a sure indication could always be given by any of them, if it were made the index by which to determine the period of blowing.

Very often, on adding the charge of spiegeleisen, a large and very brilliant flame rushed out of the converter for some minutes, and on examining it the red, yellow, three green, and a very brilliant purple line were seen, but no blue lines.

Third.—Some Experiments on the Examination of the Flame by means of Coloured Glasses.

I shall now proceed to describe some experiments made with coloured glasses on the Bessemer flame. I may mention that what led to them was that my brother was compelled to get very dark spectacles to protect his eyes, which were not very strong, from the intensity of the light of the flame. The first pair made completely overcame the brilliancy of the flame, without imparting any colour to it; but on ordering a second pair, they showed so much colour as to render them useless. On appealing to the workman who had made them, he found that no note had been kept of the kinds of glasses which had been used in the first pair; and although several attempts had been made to repeat them, the second pair sent was the best he could accomplish; and they had appeared colourless to sunlight. The thought then occurred that, as the brilliancy of the flame varies considerably during its existence, a variation in the *amount* of transmitted *light* might be found to affect, in proportionate degree, the power of some coloured glasses to absorb other colours in combination with them, and that a combination of colours might be found to give, with a small quantity of transmitted light, a distinct colour, which could be quite absorbed when a larger quantity of light was passed through the same glasses.

Another, and perhaps the most important consideration which led to the following experiments, was that the flame itself has a varying chemical composition, as the silicon, manganese, carbon, and iron become successively attacked, and that the *temperature* of the flame at these various stages must necessarily be altered, giving rise, of course, to various colours or shades of colour in the flame. If, therefore, a combination of coloured glasses could be found which would absorb the colour due to the flame at a particular temperature, it seemed clear that a *change* of temperature would become immediately visible, on account of an accession or diminution of colour in the flame, as thus observed.

It is probable, too, that the colour possessed by the flame at its different stages is due to the various elements which are at these periods being volatilized; but the spectroscope does not throw much light on this supposition.

The first combination of coloured glasses which I have noted are a

Ruby and Emerald.	It was found that these colours mutually destroyed each other. The Bessemer flame, when viewed through them, appeared white and without brilliancy.
Ultramarine blue, Dark yellow.	This combination gave the same effect as above.

With a combination consisting of—

Ultramarine blue, Dark yellow, Ultramarine blue, Emerald,	The flame appeared of an emerald colour, but was dark and without brilliancy.

In the next experiments the dark yellow and one blue were replaced by a light yellow and neutral tint, thus:—

Ultramarine blue, Light yellow, Neutral tint, Emerald.	The appearance of the flame in this case was similar in colour to that afforded by the above combination, but appeared of considerable brightness.

In the next experiments the light yellow and neutral tint were replaced by a dark yellow and red respectively, thus:—

Ultramarine blue, Dark yellow, Ruby, Emerald.	The flame at first was dimly seen and without colour; when it reached its maximum brilliancy it still appeared white through this combination.

With these five combinations the appearance of the sun, as seen through each of them, was similar in character to that of the flame, but more powerful in degree.

In the subsequent experiments the combination was as follows:—

Ultramarine blue, Dark yellow, Neutral tint, Ultramarine blue.	The flame appeared at first of a ruby-red colour, increasing in size and intensity as the "blow" progressed, the edges of the flame acquiring a lighter shade of red; but the colour was too strong to admit of the changes being easily determined. Sunlight through this combination was slightly yellow.

In the succeeding experiments, one of the blue glasses was replaced by a light yellow, giving a combination of

Ultramarine blue, Dark yellow, Neutral tint, Light yellow.	The flame appeared at first of a yellowish red colour. As the "blow" progressed, this colour became whiter, with flashes of redder flame occasionally through it. At the flame's maximum brilliancy the edges assumed a light red colour (nearly white), while at the root and centre of the flame the colour was of a darker yellowish red. When the flame dropped (at the end of the "blow"), it returned to a yellowish red colour, somewhat similar in appearance to the effect produced at the beginning of the "blow." Sunlight appeared slightly yellow.

It will be observed that this combination gave nearly the desired effect, viz., a variation of depth of colour due to the differences of temperature or brilliancy of the flame at its different stages of progression. The yellowish tint, however, always present, showed a defect in this combination, to overcome which further trials were made. Among other devices, the light yellow was omitted, and the flame was observed with

Ultramarine blue, Dark yellow, Neutral tint.	The flame appeared still red, and with the yellowish tint, though in such small degree as to show that the desired result was not far off. Sunlight appeared dim and slightly yellow.

In the concluding experiments the neutral tint was replaced by a blue glass, with the object of ascertaining whether the yellow colour could be corrected by the omission of the red or the blue component of the neutral tint, thus:—

Ultramarine blue, Dark yellow, Ultramarine blue.	This combination was perfectly successful, the lingering trace of yellow being removed.

I shall now describe more fully the general appearance of the flame through it.

For the first four or five minutes all is dark, the chimney is invisible, nothing but the mouth of the converter can be made out, which appears slightly red, the sparks coming from it being scarcely visible. As the blow progresses, the flame, still red in colour, increases in size and luminosity, while the outline of the vessel becomes visible. In about twelve to fifteen minutes the flame begins to lose its colour, becoming violently agitated, flashes of a lighter and brighter flame shooting up occasionally.

In about fifteen minutes a purple tint becomes visible round the mouth of the vessel, the flame gradually acquiring a white colour towards the edges.

When the flame has reached its maximum brilliancy, it appears bright and nearly white, with the edges purple. The red colour thereafter begins to re-appear at the mouth of the vessel and centre of the white flame, gradually extending until the whole flame appears of a light red colour.

Then, with the peculiar hollow sound heard in the vessel always preceding the drop, the centre of the flame begins to acquire a deeper colour. This quickly extends and deepens. Within a minute or so of the drop, the whole flame becomes crimson, and loses its brilliancy, and within half a minute it suddenly goes back to very nearly the red colour it had at starting.

This combination of glasses is now in daily use in the Atlas Works, Glasgow, its indications being so marked and unmistakeable as to render its use safe in the most inexperienced hands. This little instrument, or "Chromopurometer," as it is proposed to call it, is arranged as follows:—One of the blue glasses and the dark yellow one are fixed in a rectangular frame, carrying at its foot a hinge; to which the thin frame holding the other blue glass is attached, and at its top a spring-catch, to hold this smaller frame when in its shut position, and also carrying a pin and set screw for attaching the whole instrument to the hat of the observer, so as to place it before his eyes.

The object of having the glasses thus divided is to give facility for the observation of the flame through the combination of three, while during the pouring two being sufficient, the third one is allowed to hang down, when it serves to protect the lips from the great heat of the ladle and liquid steel.

In conclusion, it is probable that by carefully noting, by means of coloured glasses, such as those described, the amount of light (as determined by the shade of *colour* visible) emitted by flames of known temperature, a scale might be formed which would enable us approximately to measure the temperature not only of the flame of the Bessemer converter, but also that of many flames which have hitherto been considered beyond reach of our ordinary methods of measurement.

V.—*On the Igniting Point of the Vapours of some Commercial Products.* By Mr. W. R. Hutton.

Read before the Chemical Section, December 21, 1868.

It is a well-known fact that many commercial products at certain temperatures give off an inflammable vapour; and my object in bringing this paper before the Chemical Section is to give the results of comparative trials of the igniting points of a few of the leading articles of commerce, and also to explain the method employed by me in testing, which is very simple and sufficiently accurate.

In commerce there are several substances which, at the ordinary temperature of the atmosphere, are sufficiently volatile to emit enough vapour to form, with atmospheric air, an explosive mixture. There are many others which do not volatilize at quite so low a temperature, but which in a warm room, or exposed to the sun's rays, do give off vapours sufficient to render them dangerous; and there are others, again, that require to be considerably raised in temperature ere vapour is evolved, and, in consequence, may be considered sufficiently safe where ordinary care is employed.

I wish it to be distinctly understood that it is the vapour evolved from ordinary commercial substances, and not the point at which the substance itself will ignite, that my results refer to. To illustrate the difference in the igniting point of the vapours evolved from different articles of commerce, I pour into one glass a small quantity of sulphuric ether, and into another glass the same volume of ordinary paraffin oil. The one substance—ether—is known to be very volatile, and on bringing a light to within half an inch of its surface an explosion takes place; the other—paraffin oil—is found not to be explosive at the temperature of this room, as it requires a higher temperature to evolve vapour before an explosion will take place.

In the subjoined table, showing the results of experiments made by me, the samples having been purchased in the usual way, I give the specific gravity of the different commercial products, and the temperature at which their vapour explodes when a lighted taper is kept at 1½ inches from the surface; and also the temperature at which the vapour explodes when the lighted taper is kept at only half an inch from the surface:—

IGNITING POINT OF THE VAPOURS OF SOME COMMERCIAL PRODUCTS.

	Specific Gravity.		Taper 1¼ inches from Liquid. Degrees Fahr.	Taper ¼ inch from Liquid. Degrees Fahr.
Sulphuric Ether,	·747	under	53	—
Bisulphide of Carbon,	1·270	,,	53	—
Petroleum Spirit,	·706	,,	53	—
Paraffin Spirit,	·751	,,	70	68
Benzole, 90 per cent.,	·861	,,	74	71
Crude Paraffin Oil,	·849	,,	74	72
Do. Naphtha,	·884	,,	78	74
Brandy,	·940	,,	—	85
Wood Naphtha,	·840	,,	88	81
Crude Paraffin Oil,	·891	,,	89	84
Do. Naphtha,	·881	,,	90	86
Holland Gin,	·930	,,	—	90
Rum,	·936	,,	—	90
Methylated Spirit,	·827	,,	97	86
Burning Coal Naphtha,	·859	,,	100	91
Spirit of Wine,	·817	,,	104	73
Whisky, 25 O.P.,	·893	,,	109	83
Do., 11 O.P.,	·905	,,	110	84
Petroleum Oil,	·801	,,	118	110
Light Pitch Oil,	·920	,,	119	109
Resin Spirit,	·922	,,	122	106
Turpentine,	·875	,,	130	119
Sherry Wine,	·993	,,	—	130
Port Wine,	1·003	,,	—	130
Refined Paraffin Oil,	·809	,,	134	123
Do.	·814	,,	138	127
Fusel Oil,	·850	,,	140	129
Resin Oil,	·987	over	212	—
Heavy Pitch Oil,	·950	,,	212	—

It will be observed that the specific gravity bears no relation to the temperature required to expel vapour from many of the products mentioned in the table, and this, in some instances, arises from the fact that they are not isolated chemical substances, but consist of distinct compound bodies mixed together, the lighter of which usually, but not always, distils off first. This is very well shown from the results obtained in experimenting on the two samples of crude and the sample of burning naphtha, the benzole having been separated from the latter by fractional distillation. In the crude naphtha there always exists a large proportion of tarry matter and naphthaline; and with a gravity approaching to ·890, as compared with burning naphtha which has been freed from all tarry matter, and has a gravity not exceeding ·860, it is not to be expected that

the crude will give off vapour as readily as the refined. This has been the case, however, as is indicated by the table of results. The crude gave off vapour at a much lower temperature than the refined burning naphtha; and the same remark applies to the results obtained from crude and refined paraffin oils from which paraffin spirit has been separated. In the case of spirit of wine and different proportions of water, and also of liquids that will mix with water, a deduction from the specific gravity might be made, which would at once indicate the igniting point of the vapour, and also the percentage of spirit in it; this, however, I have not gone into. The proportion of volatile matters to be found in different crude commercial substances is exceedingly variable, and therefore no line for guidance do I offer; but in manufactured articles of commerce, where a volatile and a less volatile mixture are together, the manufacturer and the merchant have it in their power to exact a standard at which the vapour will not ignite. A very small percentage of a volatile compound is sufficient to make the whole bulk dangerous, and in some instances accidents from this circumstance are very apt to arise. In the printed table I have light pitch oil, the vapour of which explodes at 119° Fahr.; this point of ignition is not what is considered at all dangerous as compared with bisulphide of carbon or benzole; it is, however, equally dangerous, and for this reason,—that the latter is known to give off inflammable vapour which ignites at a low temperature, while the former, on account of its familiar name—pitch oil, or creosote—is looked upon as not at all explosive. In this sample of light pitch oil, the volatile matter which gave off inflammable gas at 119° did not exceed 2 per cent., after which no combustible vapour was given off until a temperature of 180° was reached, thus clearly showing that the low explosive points of the vapours of some commercial substances depend upon a very small percentage of volatile extraneous matter.

Now I shall explain the small apparatus used in estimating the igniting point of the vapours, and which is very simple.

It consists of a water bath, with basin thermometer and spirit lamp. In operating, I put the same quantity of cold water into the bath each trial, in order that the time required to raise the temperature of the water is as nearly as possible the same. Into the small basin I put a known measure of the liquid under examination (in this instance, also, the same volume is always used); the thermometer is then adjusted with the bulb immersed under the liquid in the basin. The spirit lamp is now lighted and placed under the bath; the water in the bath is gradually warmed, which, in its turn, heats

the liquid under trial. The rise of temperature is indicated by the thermometer, and by means of a lighted taper and careful attention it is easy to catch the first flash of vapour evolved. In order to have exact comparative trials, it is not only essential to have all the experiments conducted on the same principle as regards detail, but it is also of the greatest importance that the surface of the liquid, and the taper used in catching the exact point at which the vapour explodes, shall be at an equal distance in each case. This point is of the first importance to all who test the igniting point of vapours; and to explain this statement more clearly, I have printed on the table the results of experiments made on the same commercial samples, keeping the lighted taper 1½ inches from the surface of the liquid in one case, and in the other at only half an inch from the surface of the sample under trial. The results are as expected: when the vapour has to diffuse and mix with atmospheric air through a space of 1½ inches, it is found that a greater temperature is required in order to evolve the larger quantity of vapour than in the experiments of only half an inch between the lighted taper and sample; and this is explained by the circumstance that the vapour, immediately on being liberated, mixes with the small volume of atmospheric air in the experimental basin, forming with it a mixture which, on meeting a light, explodes. In the other set of experiments a greater temperature is required to disengage a larger volume of vapour to mix with the greater proportion of air.

In this paper I have carefully avoided mention of the relative danger of the articles of commerce examined by me. The table gives, however, the names of several compounds, the vapours of which readily explode; and it is with the object of having a uniform method of testing that point of danger that I now submit a method which I consider sufficiently accurate for all comparative trials. Without a uniform method no two results will agree; but with a recognized method, both manufacturers and merchants would know what the igniting point of the vapour of commercial substances exactly means, and a security to consumers and others that does not now exist would be obtained.

Note.—The Petroleum Act of 1868 enforces a uniform method of testing the point at which vapours are evolved to form explosive mixtures with air; but this applies only to paraffin, petroleum, and coal oil products, and does not refer to other commercial substances, several of which are equally, and others more dangerous, than paraffin and petroleum oil.

Dr. Wallace gave additional information relating to the new

Petroleum Act, and described the apparatus which must be used for testing in order to conform to its requirements.

DR. CLARKE stated that, in the case of liquids having a low inflaming point, the temperature at which the first flash took place was generally only a few degrees below that at which the bulk of the liquid was inflammable, but that with liquids which had a high inflaming point, the temperature at which the first flash took place was removed from that at which the liquid itself inflamed by 10° or even more. He also stated that he believed the insurance companies had divided oils into three classes, having different inflaming points; the first, or least inflammable, being represented by olive oil; the second, by Price's cloth oil, which ignites at about 346° Fahr.; and the third, embracing all oils having a lower igniting point than Price's cloth oil, a margin of a few degrees being allowed. He also pointed out that the igniting point of an oil (the only test required by insurance companies) was no criterion of the readiness with which it undergoes spontaneous combustion when spread over a cotton surface.

MR. TATLOCK believed that much misapprehension had arisen from a misunderstanding on the part of commercial men as to the true meaning of the term "igniting point," and referred to the fact that the igniting point, properly so called, of any gas or vapour was seldom, if ever, under a red heat; whereas the igniting point, commercially speaking, was simply the point at which sufficient vapour was given off to form an explosive mixture with air in contact with a red-hot body, the latter condition requiring always to be fulfilled before an explosion could happen.

VI.—*A Chemist's View of the Sewage Question.* BY MR. EDWARD C. C. STANFORD, F.C.S.

Read before the Chemical Section, April 19, 1869.

ABOUT twelve months ago I read a paper on this subject before the Sewage Association of Glasgow.* Since then the members of that association, with all their varieties of opinion, have passed one unanimous resolution:—"That whatever system be adopted, the excreta must be kept out of the public sewers;" the expression of a conviction which will be that of any patient inquirer into this difficult question.

* Vide *Chemical News*, vol. xix., p. 253.

In the paper referred to, I endeavoured to show that, whatever may be the best, the present water-closet system, with all its boasted advantages, is the worst that can be generally adopted. Briefly, because it is a most extravagant method of converting a mole-hill into a mountain. It merely removes the bulk of our excreta from our cities to choke our rivers with foul deposit, and rot at our neighbours' doors. It increases the death-rate, as well as all other rates, and introduces into our houses a most deadly enemy in the shape of the sewer gases.

Since then the report of Messrs. Bateman and Bazalgette has appeared, and it proposes (what every one knowing the views of the authors would at once have predicted) to put down miles of costly sewers to carry the excreta to the Ayrshire coast, where, perhaps, the inhabitants may oblige us to take it back again; in other words, to commit the error of London, and wake up in a few years to the same bitter repentance.

We can't be surprised at this; we can't expect homœopathic treatment from an allopathic physician, especially if, as in this case, "bleeding" is to be again the universal cure. The engineer's treatment of town excreta always reminds me of the country doctor in America, who put all his feverish patients through a course of convulsions, because, though he didn't understand fevers, he could cure fits. In our numerous discussions I have always maintained that chemists have been most unfairly treated in this matter. The public like to see what they pay for; they can see bricks and mortar, and therefore have allowed engineers to give them an intimate pocket-purse knowledge of this expensive commodity, for which they have paid in more than one sense—through the nose. Engineers have too fondly believed that water is the great purifier, and so they dilute the excreta with 365 times its bulk of water, and reduce its value to 1*d.* per ton, and then turn round on the chemist and expect him to reverse the process, pick out the penny, and repay the expenditure. Now, if it were a simple mixture—if it were only to separate the grain of wheat from the sack of chaff—the problem would be difficult enough; but we know the case to be far worse than this: it is the handful of yeast in the sack of flour that we are called upon to extract, and the fermentation of which we are expected to prevent, after it has occurred. A small portion of dilute sewage mixed with a large excess of water soon renders it all equally offensive; and the problem of extracting its value is one which no chemist need ever attempt to solve.

The water-closet, with many apparent advantages, and with all our

prejudices in its favour, carries an attendant train of evils, which, I am fully persuaded, will ultimately doom it to oblivion.

As, therefore, engineers have not put the subject fairly before chemists, I propose to take a noble revenge, and put the subject fairly before engineers. I ask them why they consider water to be the only vehicle for removing excreta? why not earth? why not air? Have they ever fairly investigated or thoroughly experimented on the other methods? Have they not rather confined their studies to fits, and forgotten fevers?

So many attempts have been made by chemists to pick up the halfpence that engineers have so plentifully flung into the mud, that I cannot even notice them, except to remark that, in the opinion of all the scientific chemists who have specially investigated these attempts, they have all signally failed.

I must allude, however, to the process of Mr. Chapman, as one of the latest methods of dealing with town sewage. This is a process of distillation after treatment with lime, and thorough putrefaction. He, however, confesses his difficulty, by wishing to reduce the sewage of this city from 31,000,000 gallons daily to 1,000,000 gallons. This of course requires a complete alteration in the existing system, and it still dilutes the excreta with more than ten times its bulk of water. The lime process, and the putrefaction required to decompose the urea, would be extremely offensive, and require vast storing tanks. In working 1,000,000 gallons daily (it would more probably amount to 2,000,000 gallons) he would have to treat 4,464 tons daily, the total chemical (not the extractible) value of which is 2*s.* 6*d.* per ton, and he expects to do this with 20 tons of coal. He proposes to adopt an ingenious arrangement of eight boilers steaming exhaustively to distil off the ammonia, heating up the feed sewage after precipitation by lime, by the hot water discharged from the boilers, by a kind of brewhouse refrigerator, with its object reversed. He expects to distil off $\frac{1}{12}$th; but I think this must be at least $\frac{1}{10}$th, or 100,000 gallons evaporated by 20 tons of coal = 5,000 gallons to 1 ton.

The report of Professors Lyon, Playfair, and Johnstone, puts the average evaporation for Scotch coal at 7·7 tons, or 1,712 gallons per ton; and at this rate 58 tons would be required for the mere evaporation. Then, for raising the heat, the same report says that 1 ton Scotch coal raises 56 tons water from 32° to 212° Fahr.; or say, 50 tons water from 52° to 212° Fahr.

This requires 96 tons, making a total of 148 tons daily.

Mr. Chapman therefore expects to save by heating feed water and by exhaustive steaming a total of 128 tons daily, or 600 per cent.

Can this be done? If it can, then, whatever may be the result of his process as applied to sewage, it will make him the greatest and most daring authority on that equally important subject, the economy of fuel. He puts down no loss for radiation. This should, I think, be at least 10 per cent., which would require nearly as much as his total calculated expenditure for fuel. In using eight boilers of 4,000 gallons each, he expects to get off all the ammonia in half an hour's steaming of each. Now, we all know that the estimation of free ammonia in the laboratory is one of the most tedious processes, requiring a lengthened ebullition; and the experience of distillers on the large scale amply corroborates this, and proves that it does not pay to distil ammoniacal liquids containing under 1 per cent. of ammonia (some manufacturers double this estimate). The total amount in the sewage to be distilled would be under 0·2 per cent.

I think, therefore, that the process of Mr. Glassford, of evaporation with sulphuric acid, for which I must refer you to his pamphlet *On London Sewage*, is better than this. Fuel is the great question in both; but in his the results are certain; in Mr. Chapman's they are problematical. Both are, however, connected with the water system, which I believe to be a mistake; and I think we must ultimately come either to a system like Captain Lieurnur's, by what may be called pneumatic despatch, or to the dry-closet system. Of the former I have fully treated in a former paper, and wish now to speak this evening more particularly of the latter. During the past year Moule's dry-closet has been largely introduced. All who have used it speak in the highest terms of its efficiency; and there are already strong indications of its becoming the system of the future. It is the only one that has succeeded during the hot fortnight at the Wimbledon meeting. The objections urged against the system when earth is used are, *first*, the large quantity of earth required—three and a half times the weight of the excreta; and *second*, the difficulty of obtaining the quantity required, and of drying it. Now, both these difficulties are disposed of by using charcoal. I employ by preference sea-weed charcoal, because it is the most porous, and the best absorbent, and the cheapest, and could be obtained in large quantity. It only requires one-fourth of the weight, compared to earth; and when the mixture is removed and placed under cover, it soon dries. This mixture can be stored for any length of time, and used again several times. When convenient, it is re-burned like the char in sugar refineries, except that this process is carried out in apparatus which admits of collecting the ammonia and other products condensed. The whole of the ammonia is collected in this way; whilst the

phosphoric acid, potash, and mineral matters accumulate in the charcoal, together with the carbon from the organic constituents of the excreta. In this way the weight of the charcoal will be increased to the extent of about 5 per cent. with each using, and if dried and re-used five times, about 25 per cent. with each re-burning. With this constant addition the char will not require replacing with fresh material, so that its cost is only a primary outlay—the ultimate result being that the excreta is deodorized by a charcoal derived from itself; and a company working this process would, in addition to securing the whole of the ammonia, become sellers of an animal charcoal second only in value to that obtained from bones, to the extent of, in Glasgow, if the process were general, 19 tons a day, or 6,935 tons a year,—the total quantity of excreta which Glasgow has to remove being taken at 385 tons a day, and its value at 29*s.* 6*d.* per ton = £569, as calculated in my former paper. The ultimate result being the same, any charcoal may be used at first. The process may be carried out without odour from the closets to the finished products. Of course, it may be modified; for instance, suppose the char to be used five times, and only dried, the addition to its value would be as follows. I take equal parts, as this charcoal will absorb at least an equal weight of even urine:—

$$\left.\begin{array}{l}\text{1 ton seaweed char, at £2,}\\ \text{5 tons excreta, at 29}s.\ 6d.,\end{array}\right\}\begin{array}{l}=\text{30 cwt. manure, at £9, 7}s.\ 6d.\\ =\text{£6, 5}s.\text{ per ton.}\end{array}$$

Or if re-burnt, it would yield 25 cwt. of charcoal, and the whole of the ammonia would be secured in the distillation. Dr. Wallace estimates the cost of re-burning char in sugar refineries at 3*s.* 6*d.* per ton for labour and fuel, containing 31 per cent. moisture, which would be much over that referred to. Here, then, we have a simple process for recovering the whole of the value from excreta, of general application, and the results of which can be predicted by chemists with absolute certainty, as far as those products to which we at present attach value are concerned; but the uncertain portion is, as usual, the most interesting; for in the destructive distillation of excreta we are exploring a new field, which promises great interest.

The distillation generally is remarkably similar in its products to that of bones, and also to that which most resembles it, of sea-weed. Besides ammonia, acetic acid, with a little butyric acid, acetone, and pyrrol, are the most marked bodies. I cannot speak more definitely of these products in this paper, as they are still under investigation.

The following analysis of urine is taken from Miller, to represent its average composition in 1,000 parts, specific gravity 1·020. The calculations of nitrogen are appended.

		Water.	956·80		In 100 parts of Solid Matter.	
Solid Matter, 43·20	Organic. 29·79	Urea, . . .	14·23	N. 6·64	33·00	N. 15·40
		Uric Acid, . .	·37	N. ·12	·86	N. ·27
		Alcoholic Extract,	12·53	6·76	29·03	15·67
		Watery Extract,	2·50	= Ammonia, 8·2	5·80	= Ammonia, 19·0
		Vesical Mucus, .	·16	= Sulphate Ammonia, 31·86	·37	= Sulphate Ammonia, 73·72
	Inorganic. 13·35	Chloride Sodium,	7·22		16·73	
		Phosphoric Acid,	2·12		4·91	
		Sulphuric Acid, .	1·70		3·94	
		Lime, . .	·21		·49	
		Magnesia, . .	·12		·28	
		Potash, . .	1·93		4·47	
		Soda, . . .	·05		·12	
			999·94		100·00	

The average portion voided by each individual may be taken at 40 ounces urine and 4 ounces fæces. Total, 44 ounces daily = 1·7 ounces solid from urine, and 1 ounce solid from fæces. Total, 2·7 ounces solid daily.

The following analysis of the fæces is by Berzelius:—

	Water,	75·3	
Solid Matter, 24·7	Bile, ... ·9; Albumen, . . . ·9; Extractive Matter, 2·7; Salts, . . . 1·2 . . .	5·7	Containing, according to Playfair, 15 per cent. nitrogen and 45 per cent. carbon, and about 25 per cent. of ash. Nitrogen = 70·71 of sulphate ammonia, in dry solid. Fæces contain 4·55 per cent. ammonia = 17·65 per cent. sulphate.
	Insoluble residues of digested food,	7·0	
	Insoluble matters added in intestinal canal, mucus, biliary resin, and peculiar animal fat, . .	12·0	
		100·0	

This ash contains, according to Porter—

	Ash of Fæces.	Ash of Urine Calculated.
Chloride Sodium, . . .	1·33	54·15
Phosphoric Acid, . . .	36·03	15·89
Sulphuric Acid, . . .	3·13	12·73
Lime, ...	26·46	1·57
Magnesia, ...	10·54	·89
Potash, ...	6·10	14·45
Soda, ...	5·07	·38
Peroxide Iron, . . .	2·50	
Carbonic Acid, . . .	5·07	

Assuming, then, the proportions voided to be 17 dry from urine to

10 dry from fæces, the resulting chars may be expected to have the following composition:—

	Urine.	Fæces.	17 to 10, Mixed Excreta.
Percentage of Char in dry solid, .	50	70	57
Ammonia as Sulphate, . . .	73·72	70·71	72·60
Percentage Composition of Chars.			
Carbon, ...	33·33	45·00	37·65
Chloride Sodium, ...	36·10	·33	9·51
Phosphoric Acid, ...	10·60	9·01	10·01
Sulphuric Acid, ...	8·49	·78	5·63
Lime, ...	1·05	6·61	3·11
Magnesia, ...	·60	2·63	1·35
Potash, ...	9·64	1·52	6·63
Soda, ...	·26	1·26	·63
Peroxide Iron, ...		·62	·23
Carbonic Acid, ...		1·26	·46

The nitrogen in the mixed excreta, in the proportions voided, is equal to 4·49 per cent. of sulphate of ammonia.

In the char from urine the phosphoric acid is principally combined with potash, and therefore soluble. This char alone would be a valuable manure, as containing a large proportion of soluble phosphates. But the result of commencing with sea-weed charcoal, which is rich in carbonate of lime, will be to form phosphate of lime at the expense of the carbonate; in other words, to form, by treatment with urine, re-burning, and washing, the animal charcoal required by the sugar refiner. This expected result is verified in the following tables of analyses. I regard the phosphate of lime thus gradually formed, from its minute state of division, to be quite equal in agricultural value to ordinary soluble phosphate. The washed residual char from fæces is at once available for the refiner, as it contains about 26 per cent. of phosphates of lime and magnesia, with but a small proportion of carbonate. I know no reason why the product of disintegrated bone and muscle should not be used for this purpose as well as the bones themselves.

In distilling 100 tons of the dry product, from mixed excreta, we should obtain 72 tons of sulphate of ammonia, and 57 tons of a charcoal containing 10 per cent. of phosphoric acid in its most available form, for manure, and 6 per cent. of potash. It will be seen from Berzelius's analysis that nearly 50 per cent. of the dry fæces consists of fatty matter. How will this appear in the distillation? In a population of 500,000, this item amounts to nearly 7 tons a day!

I expected a loss of ammonia in drying, but it is very small, and appears to arise from the free lime in the char, as it will be seen farther on that the loss decreases in using the char with urine. I found the total loss in drying by artificial heat, with new char, to be 2·06 per cent. of the total ammonia, or 0·105 per cent. of the urine employed. I append analysis of 1 lb. char, which was re-burnt fifteen times with an equal weight of urine. A portion of the char was lost, which prevents my giving the total increase in weight. I believe, however, the addition of carbon would be too slight to effect an increase in the total with so many re-burnings; the percentage is decreased.

	Char Used.	After Re-burning.	Increase per Cent.
Water, ...	10·0	2·80	...
Soluble Salts, ...	·6	11·15	10·55
Insoluble, ...	89·4	86·05	...
SOLUBLE.			
Chloride Sodium,* . . .	...	8·75	8·75
Sulphuric Acid, ...	·3	·34	·04
Phosphoric Acid, ...	...	2·00	2·00
Potash, ...	·3	2·40	2·10
INSOLUBLE.			
Carbon, ...	54·4	29·40	...
Silica, &c., ...	9·1	13·10	4·00
Phosphate Lime, ...	4·8	20·05	15·25
Carbonate Lime, ...	17·4	19·75	2·35
Carbonate Magnesia, . . .	3·4	3·40	...

The urine used appears to have been deficient in sulphates and rich in phosphates, these two ingredients being subject to considerable relative variation.

The distillates gave 192 ounces of liquid containing free ammonia equal to 3,047 grains sulphate, or 2·9 per cent. of the urine, showing a slight loss inseparable from destructive distillation on the small scale. The charcoal should be used at least five times before re-burning, and for urine alone it may be employed ten times.

I append a table showing the analytical results of this process with urine.

No. 1 is from charcoal dried up with ten times its weight of urine

* In this and the following analyses the whole of the chlorine has been calculated for convenience as chloride of sodium, which, in some cases, is therefore too high.

before re-burning. No. 2 has been treated with twenty times its weight, No. 3 with fifty times its weight, and No. 4 with 100 times its weight of urine before re-burning.

It will be seen that in No. 4 more than the theoretical amount of ammonia is obtained. That from Nos. 1, 2, and 3, is obtained by simple destructive distillation. No. 4 only yields ammonia equal to 50·48 per cent. of sulphate when treated in this way, the quantity given, 105·64 per cent., being that obtained with soda lime. The residual nitrogen is not left in the char, but goes off in the distillation in some other form than ammonia. I shall recur to this subject in a subsequent paper. The retention of nitrogen after drying is, however, extraordinary, when the product yields ammonia equal to 105 per cent. of sulphate. No Peruvian guano can be compared to this in fertilizing value.

The washed chars acquire the composition which fits them eminently for the sugar refiner.

	Increase per Cent.				Increase per 1,000 Grains of Urine.			
	1.	2.	3.	4.	1.	2.	3.	4.
Dry Solid Matter, . .	33·30	62·60	210·00	347·94	33·30	31·25	42·00	34·79
Char, ...	7·50	12·90	80·40	151·96	7·50	6·45	16·40	15·19
Ammonia Sulphate, .	31·70	86·90	51·12	105·64	29·00	29·90	31·60	47·31

RESIDUAL CHARS.

	Composition per Cent.					Increase per Cent.				Increase per 1,000 Grains of Urine.			
	Ordinary Char	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
Water, ...	10·00	1·60	3·00	...	...	...	...	...	...	...	...	...	...
Soluble Salts, . . .	·60	15·80	19·80	39·40	52·20	15·20	19·20	38·80	51·60	20·40	15·70	24·30	22·78
Insoluble, ...	89·40	82·60	77·20	60·60	47·80	...	...	...	*41·60	2·04	23·90	19·60	12·47
SOLUBLE.													
Chloride Sodium, . .	...	5·40	13·10	28·02	24·70	5·40	13·10	28·02	24·70	7·15	10·60	17·30	11·06
Sulphuric Acid, . .	·30	2·05	3·29	3·77	3·77	1·75	2·09	3·47	3·47	2·33	2·64	2·21	1·62
Phosphoric Acid, . .	...	2·20	·40	trace	1·60	2·20	·40	...	1·60	2·92	·32	...	·71
Potash, ...	·30	2·60	4·99	7·00	10·38	2·60	4·69	6·70	10·08	3·32	3·89	4·10	4·62
INSOLUBLE.													
Carbon, ...	64·40	37·40	40·00	35·40	28·20	...	...	...	*36·20	*4·50	5·30	11·06	7·16
Silica, &c., . . .	9·10	13·60	10·00	8·00	4·40	4·50	·90	...	*4·60	8·98	3·57	8·14	1·06
Phosphate Lime, . .	4·60	8·00	9·60	11·40	10·20	3·20	4·80	6·60	5·40	5·84	5·40	8·10	4·08
Carbonate Lime, . .	17·40	20·40	13·20	4·20	1·15	...	...	...	*16·25	9·73	2·00	*·86	*1·22
Carbonate Magnesia, .	3·10	5·40	3·16	1·93	1·20	2·30	·06	...	*1·90	4·06	·08	·57	·38

* Decrease.

WASHED CHARS.

	Composition per Cent.					Increase per Cent.			
	Ordinary Char.	1.	2.	3.	4.	1.	2.	3.	4.
Carbon, ...	54·40	45·30	51·80	58·40	59·00	*9·10	*2·60	4·00	4·60
Phosphate Lime, . .	4·80	9·60	12·40	18·80	21·34	4·80	7·60	14·80	16·54
Carbonate Lime, . .	17·40	24·60	17·10	6·90	2·40	7·20	*·30	*10·50	*15·00
Carbonate Magnesia, .	3·10	6·50	4·10	3·10	2·51	3·40	1·00	...	*·59

* Decrease.

The experiments with closet excreta are unfinished, and it is difficult in working on small quantities to obtain uniform results. We find one of Smith's dry closets use about half a pound of char per charge, the charge of dry earth being 2 lbs. Moule's closet uses rather less. There were seven uses of the closet in our first experiment, and the contents were re-burnt at once without previous drying.

Weight before Distillation, ...	130 ounces.		
Residual Char weighed, ...	48 ,,		
Weight of Excreta, . . . 82 ounces =	11·7 ,,	per use.	

The distillation gave 66 ounces of gas liquor, containing free ammonia = 2·8 ounces sulphate = 3·4 per cent. of the mixed excreta. This represents only the free ammonia, or that existing as carbonate; a portion present in combination with acetic acid was not estimated.

The same method is equally well adapted for treating pot ale from distilleries, and blood and offal from slaughter-houses. The former is an important subject in Glasgow; and I can in this paper only shortly allude to it. According to Dr. Wallace, one of the distilleries in Glasgow sends into the sewers 83,000 gallons of this pot ale, containing nitrogen equal to 118 grains of ammonia per gallon; so that the daily discharge of this one distillery is equal to the total excreta of 48,970 persons, or one-tenth the population of Glasgow.

The process can be adapted with ease to urinals as well as closets. I am enabled to exhibit some mixtures of charcoal and night-soil made twelve months ago. I was curious to know if these mixtures had gone further in the oxidation of the ammonia and formed some nitrates, but not a trace can be detected.

I submit that the dry-closet system, with this process, has the following great advantages:—

1. Total freedom from all odour. All must have noticed sometimes

the sickly odour of a water-closet, arising not from the excreta, but from the gas from the sewers.

2. Certain prevention of all contamination and spread of infectious diseases arising from sewer leakage into our wells, or sewer gas into our houses.

3. Saving of water equal in Glasgow to £40,000 a year, if the water-closet system were general.

4. Saving of expense in repairs and removal. One hundredweight of charcoal per month is sufficient for each closet when used by six persons daily, and the whole may be allowed to fall at once from the closet through a 12-inch pipe to a cesspit below the house. A cesspool is a serious evil; but I know of no objection to a cesspit.

5. By this process alone can the whole of the valuable material be recovered for our lands.

Dr. Fergus has shown some remarkable examples in which gastric fever has been traced to the escape of sewer gas through small openings eaten through the top of the soil-pipe. This appears to be a wide-spread evil. I have examined some of these specimens, and find the substance to be a sort of lead plaster, containing also lime and some fatty acid, which requires further examination. I have shown that only remedial measures can be adopted, where the water-closet system has been carried out, by placing boxes of charcoal in the closets, and filtering the sewage through charcoal before allowing it to enter rivers.

Our authorities want, of course, some grand scheme, but they must not forget that the question is one of minute details. We are assailed by a large army of small nuisances—one, at least, to every house—and we must attack them one at a time. Attacked in their united strength, they will assuredly overcome us. Ought we not rather to strike at the root of the evil? Ought we not to stop the mischief at its numerous sources, and before these can combine into a mighty force, which carries everything before it?

Let the subject be calmly and carefully discussed; let us not be carried away by great schemes and useless expenditure; let us not "strain at a gnat, and swallow a camel;" let us not leave to posterity heavy taxes, with barren wastes and desolate cities; but let us rather pay our own way, and leave our country fertile and our towns pure, and I shall never regret that, however imperfectly this subject has been brought before you, my earnest wish has been to strike "one more blow for life."

A lively discussion followed the reading of the paper, the general

opinion of the members of the Section being highly favourable to the process, which was considered the most novel and practical which has yet been introduced.

VII.—*On the Extension of the Coal Fields of England beneath the recent Geological Formations.* By Mr. Edward Hull, F.R.S., District Surveyor of the Geological Survey of Scotland.

Read before the Society, March 10, 1869.

Mr. Hull commenced by observing that the question of the exhaustion of our coal fields, which had presented itself to the mind of the late Dr. Buckland thirty years ago, had more recently occupied a considerable share of public attention, which had resulted in the appointment of a Royal Commission to investigate this and kindred subjects. The lecturer considered the present a favourable opportunity for coming to some definite conclusions regarding the actual areas (whether concealed beneath more recent strata, or superficial) of the British coal fields, both on account of the great advance made in our knowledge of the physical geology of the British Isles within the last few years, and because the geological surveyors had nearly completed the surveys of the English coal fields on the large ordnance maps, whereby the relations of the coal measures to the bordering formations had been accurately determined. The lecturer then proceeded to describe the original margin of the coal formation of central England, as ascertained by actual experiment as well as on theoretical grounds—showing that there is evidence of the existence of a tract of Silurian and Devonian rocks stretching with an irregular outline across the centre of England, from Shropshire and Herefordshire, into the eastern counties, now overspread by Mesozoic strata, which rest directly upon the Silurian rocks, and under which coal does not exist. This old barrier or ridge had been detected in the district of South Staffordshire by Sir R. Murchison and Mr. J. B. Jukes, and had been penetrated in abortive coal pits south and east of Dudley. This old ridge, which was dry land in later Palæozoic times, divided the coal fields of the Midland and northern counties of England from those of Gloucestershire, Somersetshire, and South Wales, which were originally united; as were also the coal fields north of the ridge, to the very

borders of Scotland. Over this latter tract, extending from the southern uplands of Scotland into the central counties of England, the coal measures were originally continuously spread, and attained their maximum development towards the north-west of England, thinning away in the direction of the old ridge, which formed their southern margin. The coal seams also partook, though not to the same extent, of this southerly attenuation; for while there are 60 feet of workable coal distributed amongst 6,000 feet of strata in Lancashire, there are only about 30 feet distributed amongst 2,500 feet in Warwickshire and Leicestershire. At the close of the coal period there were powerful disturbances over the whole of England, and probably the south of Scotland, along lines or axes, ranging for the most part N. of E. and S. of W. These disturbances were accompanied by denudation on a grand scale, whereby thousands of feet vertical of strata were swept away, and the coal fields of Lancashire, Cheshire, and Yorkshire were dissevered from those of Cumberland and Durham. At the same period the coal field of Derbyshire and Nottinghamshire was dissevered from that of Leicestershire by the upheaval of the lower carboniferous rocks along the valley of the Trent, and to the north of the North Staffordshire coal field. This axis of elevation, along which the coal measures had been denuded away, was considered by the author to stretch under the central plain of Cheshire, emerging from beneath the Triassic formations on the borders of Denbighshire and Flintshire. Over the carboniferous rocks thus disturbed and broken, the Permian strata were spread—those of the central counties and Shropshire being physically separated by an intervening ridge of lower carboniferous rocks from those of the north of England. In Warwickshire these rocks attain a thickness of 1,800 or 2,000 feet. At the close of the Permian period another series of powerful movements of the strata, accompanied by denudation, took place along axes generally ranging from north to south. It was at this period that the Pennine range of hills, also called "the back-bone of England," was upraised. This ridge, composed of lower carboniferous strata, from off whose surface the coal measures have been swept away by denuding agencies, ranges from Derbyshire to the borders of Scotland, and dissevers the coal fields of North Staffordshire, Cheshire, and Lancashire on the west side, from those of Notts, Derbyshire, and Yorkshire on the east. From analogy, as well as from the fact of the uprise of the coal measures towards the east along the Northumbrian coast, the lecturer was of opinion that both the Durham and Yorkshire coal fields are actual basins, formed by an easterly uprising of the lower carboniferous

strata beneath the Triassic and Permian formations. This view was one very strongly advocated by Professor A. C. Ramsay, one of the most eminent authorities of our day on physical geology. At the commencement of the Mesozoic period the Triassic strata were deposited over a gradually subsiding sea bed formed of the Palæozoic rocks, attaining an enormous development in the north-west of England, and thinning away in the direction of the eastern counties. The succeeding formations of the Liassic, Oolitic, and Lower Cretaceous periods, the lecturer considered, were successively deposited against, and terminated by, the gradually shelving margin of the old ridge of Silurian rocks previously described. This view was confirmed by the boring made at Harwich, where cleaved schistose rocks of lower carboniferous age, corresponding to the Belgian series, were found underlying the cretaceous strata, without the intervention of any of the formations between these beds and the coal measures. The lecturer then referred to a diagramatic section, illustrating his views of the structure of the central and eastern counties, showing that all the evidence we possessed went to disprove the existence of coal strata under this part of England. The lecturer then alluded to the views of Mr. R. Godwin Austen, F.R.S., respecting the possible extension of coal measures under the valley of the Thames, stating that, from the uprise of the carboniferous limestone along the east side of the Somersetshire coal field, and the inferred ridge of older Palæozoic rocks under London, as described by Mr. W. Whitaker, it would appear that the evidence so far is against this view; while, at the same time, there is ample space for the existence of small basins of carboniferous strata under this part of England, should they ultimately be found to exist. In conclusion, the lecturer referred to the views of Sir Roderick Murchison on this question, as expounded on the occasion of the meeting of the British Association at Nottingham, stating that they very closely coincided with those held by himself, though formed on somewhat independent grounds; and this fact, the lecturer contended, might be taken as a guarantee of the validity of the conclusions arrived at on this question. The general result of the views of those geologists who had specially investigated this question went to show that the concealed areas of the coal fields, though undoubtedly large in themselves, were very much smaller than was generally supposed by some of the sanguine members of Parliament who advocated in 1859 the unrestricted exportation of British coal to foreign countries.

In the course of a short discussion on Mr. Hull's communication,

Mr. Edward Wunsch made some forcible remarks on the necessity

of economizing the consumpt of coal, not only in furnaces, but in household use.

The PRESIDENT, following up the same line of remark, expressed his belief that at the present rate of consumption the coal beds of the Clyde district would not last longer than a period of 150 years, and the beds of ironstone not more than 100.

VIII.—*The Salt Deposits at Stassfurt.* BY MESSRS. J. H. BALD AND JAMES MACTEAR.

Read before the Chemical Section, January 18, 1869.

THE southern part of the North German basin is divided by the Hertz into two portions which are known as the Thuringian and the Magdeburg Halberstader basins, in which salt has been raised for a lengthened period in the form of brine.

The basin covers a surface of 120 English square miles, and is filled with new red sandstone, which is not broken up by any of the older formations. It is interspersed by elevations of gypsum, which is considered a certain indication of the presence of common salt. In the Prussian mine at Stassfurt, in the Magdeburg basin, after passing through 27 feet of alluvial soil, a thickness of 576 feet of new red sand, stone is at once reached; then 213 feet of gypsum, anhydrit, and marl-the salt being found at a depth of 816 feet. In the Anhalt mine (half a mile from the Prussian one) the sandstone is entirely wanting, the salt bed being reached at a depth of 480 feet, after passing through 20 feet of soil and 460 feet of gypsum, anhydrit, and marl. (*Vide* fig. 2). The bore-holes at Schonebeck (about 15 miles from Stassfurt) show very distinctly the various strata with which the basin is filled up, as the salts gradually get deeper and deeper. Thus, at bore No. 8, the salt is 1,000 feet from the surface, the intervening strata being 200 feet of alluvial soil and 800 feet of new red sandstone. At No. 5 there is 37 feet of alluvial soil, 166 feet of mussel-chalk, and 1,277 feet of new red sandstone, the salt being 1,480 feet from the surface. At No. 6 there is 30 feet alluvial soil, 877 feet mussel-chalk, and 473 feet new red sandstone, the salt being 1,380 feet from the surface. At No. 4 there is 25 feet alluvial soil, 211 feet of what in Germany is called keuper and lettenkohle (literally, copper and letter or paper coal). This keuper is the equivalent of the saliferous and gypseous shales

and sandstones of Cheshire, a member of the "Trias," or new red sandstone formation. Lettenkohle is a variety of lignite known in the district as brown coal. Next we have 1,067 feet of mussel-chalk, 377 feet of new red sandstone, and the salt at a depth of 1,680 feet. Bore No. 3 is somewhat similar to No. 4, there being 30 feet alluvial soil, 435 feet keuper and lettenkohle, 1,087 feet mussel-chalk, 212 feet new red sandstone—the salt being 1,764 feet from the surface. (*Vide* fig. 1.)

In the Magdeburg basin the salt rests on new red sandstone, and in the Thuringian basin on mussel-chalk and magnesian limestone.

It is only at Stassfurt and Erfurt that the salt is mined; at all the other places it is obtained by means of brine wells, the liquor from which is concentrated by the *graduation* process, which consists in allowing the weak liquor to trickle through walls made of bundles of thorns and brushwood.

The graduation-houses consist of a timber framing, into which the faggots of thorns are built in regular walls. The structure is covered with a roof to protect it from the rain; but the sides, of course, are open, to admit of the free passage of air, which, together with the solar heat, forms the evaporating medium.

The walls are from 30 to 50 feet high, and of immense length, the celebrated one at Schonebeck being fully more than an English mile in length. They are placed in the manner best suited to obtain the full benefit of the prevailing wind. The house is divided into several sections, and the weak liquor is pumped up into a cistern, from which it is led by means of a perforated pipe along the top of the first division, down the sides of which it trickles into a large wooden tank underneath; from this it is pumped up and allowed to trickle through the second division; from underneath which it is pumped on to the third; and so on until it reaches the last one. In graduation-houses where the number of compartments does not exceed three, and indeed in all of them, to a greater or less extent, the liquor is pumped through the same division several times. The weak brine at Schonebeck contains 7½ per cent. of common salt, which at the finish of the graduation process is raised to about 22 per cent. In this state it is run into large tanks, of which there are eight at Schonebeck, of an aggregate capacity of about 2,500,000 gallons. From these tanks it is drawn off to the evaporating pans, as required for boiling down. At these works the process of graduation can be carried on for an average of 250 days in the year.

The boring operations were commenced at Stassfurt on the 3d April, 1839, and in June, 1843, had penetrated to the rock salt

region. In January, 1851, when it had reached a depth of 1,851 feet, the liquor from the bore contained—

Sulphate of Magnesium, ...	4·01
Chloride of Magnesium, ...	19·43
Chloride of Potassium, ...	2·24
Chloride of Sodium, ...	5·61
Total Salts, ...	31·29

However, in 1848, Professor Marchand gave it as his opinion that the salts were not mixed in the manner represented by the brine, but that pure rock salt would be found at the bottom, with the more soluble salts overlying it; and so much weight was given to his opinion, that, in December, 1851, after having penetrated to a depth of just as many feet as there were then years in the Christian era, the sinking of the shaft "Von der Heydt" was commenced, followed in January, 1852, by that of the shaft "Von Monteuffel;" and in 1856 the pure salt was found 1,066 feet from the surface. The shaft passes through, *first*, 27 feet of alluvial soil; *second*, 576 feet of sandstone, with some schist and gray limestone; *third*, 192 feet of gypsum and anhydrit; *fourth*, 21 feet of bituminous matter, mixed with anhydrit and common salt,—making in all 816 feet. Next there is 158 feet of abram or potash salts, the value of which was not recognized at first, but which now play a very important part in the industry of the country. The shaft then passes through 92 feet of rock salt, the upper portion of which is rather impure, being mixed to a considerable extent with anhydrit. This makes a total depth of 1,066 feet, and at this point the lateral workings were commenced. These consist of large galleries, the principal of which are from 40 to 60 feet broad, 20 to 25 feet in height, and about 200 feet long. The salt is wrought in a manner somewhat similar to our long-wall system: a series of holes of sufficient depth, about 6 feet or so, are drilled in the face of the salt, about 5 feet from the floor, and this depth of material is removed by a series of small blasts. This operation is repeated until a considerable space has been cleared under the overhanging mass of salt. Bore-holes are then drilled close to the roof, and by a series of simultaneous blasts a large mass of salt is dislodged. In one of those halls or galleries which we visited there was lying on the floor a mass of between 2,000 and 3,000 tons, which had been removed in this manner a few days previously. A number of boys are employed to pick out the pieces of pure salt, which only requires grinding to fit it for domestic use. The salt is removed to the pit bottom in hutches running upon rails, exactly similar to those in use

in our own coal-pits; from this they are lifted to the surface by an engine of 130 horse-power, and removed to the grinding mills, of which there are twelve at the mines. There is also a 200 horse-power engine for pumping, which lifts 13 cubic feet of water per minute.

The workings into the potash salts are opened on the other side of the shaft from the common salt galleries; for, although the salts are deposited one on the top of the other, still, as they dip at an angle of 30°, they are all wrought from the one level. (*Vide* fig. 2.)

The total thickness of the salts is 1,197 feet; and this may be said to consist of—

989	feet	Rock Salt.
36	,,	Anhydrit.
13	,,	Polyhalit.
51	,,	Kieserit.
98	,,	Carnallit.
13	,,	Hydrated Chloride of Magnesium.

This gives a composition of—

Chloride of Sodium, ...	85·82
Sulphate of Calcium, ...	4·88
Sulphate of Magnesium, ...	4·70
Sulphate of Potassium, ...	0·40
Chloride of Magnesium, ...	2·53
Chloride of Potassium, ...	1·67
	100·

We will now consider the beds *seriatim*, beginning with the lowest, which is called the *anhydrit region*, and consists of 685 feet of pure rock salt, interspersed with thin layers of anhydrit ¼ inch or so thick, and dividing the salt at intervals of from 1 to 7 or 8 inches. The salt is pure and colourless when pulverized.

The anhydrit is anhydrous sulphate of calcium, and contains a small quantity of a bituminous matter, which imparts to it its characteristic gray colour; traces of organic remains are also proved by the presence of a gas containing carbureted hydrogen, which, according to Bischof, has the following composition:—

Carbureted Hydrogen, ...	85
Carbonic Acid, ...	3
Atmospheric Air, ...	12
	100

It is present in quantities of about 3 cubic centimètres per kilo-

gramme in the rock salt, and about 8 cubic centimètres in the kali salts. It presents the appearance of air bubbles in the transparent crystals. The specific gravity of anhydrit is 2·968, and it is soluble in water to the extent of 1 part in 500.

In the second, or *polyhalit region*, we have, besides the common salt and sulphate of lime, a deposition, from what might be considered the mother liquors, of the sulphates of potassium and magnesium, which have combined, with the sulphate of calcium, to form the salt polyhalit, from which this division takes its name. Its composition is

$$2\,Ca\,S\,O_4 + Mg\,S\,O_4 + K_2\,S\,O_4 + 2\,H_2\,O.$$

It has a specific gravity of 2·720, and is immediately decomposed by water. Specimens of it are seldom found pure, as they generally contain from 2 to 6 per cent. of chloride of sodium.

This bed is about 200 feet thick, and has an average composition, according to Steinbeck, of—

Chloride of Sodium,	91·20
Anhydrit,	0·66
Polyhalit,	6·33
Hydrated Chloride of Magnesium,	1·51
	99.70

The upper layers, however, being the more impure.

In the third, or *kieserit region*, the gradual disappearance of the more insoluble salts is made manifest; for it contains on an average only 2 per cent. of anhydrit and about 60 per cent. of common salt, and from 17 to 20 per cent. kieserit, which is monohydrated sulphate of magnesium—the formula being $Mg\,S\,O_4 + H_2\,O$, and its specific gravity 2·517. Specimens found in the mine generally contain from 1 to 2 per cent. of chloride of sodium or magnesium. It is amorphous, grayish-white, and transparent, and in the air has a tendency to pass into epsoms, becoming opaque during the transformation. It is soluble in rather more than twice its weight of water (40·9 parts in 100 $H_2\,O$). When the quantity of water is not sufficient for complete solution, this salt has the peculiar property of absorbing a certain quantity of it, and setting into a hard mass, more resembling a piece of flint than anything else, and with, of course, a considerable increase of volume.

In the fourth and last division, which is called the *carnallit region*, the insoluble salts are entirely gone, and even the common salt gives place in quantity to the more soluble carnallit, the average composition being—

Carnallit, ...	55
Common Salt, ...	25
Kieserit, ...	16
Hydrated Chloride of Magnesium, ...	4
	100

Carnallit, when pure, consists of

$$K\,Cl + Mg\,Cl_2 + 6\,H_2O,$$

having a specific gravity of 1·618, and dissolving in about one and a half times its weight of water at 18° C. It is crystalline, clear, and colourless; but, as found in the mine, it varies from pure white to a deep red colour, owing to the presence of minute quantities of peroxide of iron. This peroxide of iron, when separated from the salts, presents the appearance of a coppery bronze powder; but when viewed under the microscope, it is found to consist of distinct crystals of exceedingly beautiful appearance, varying in colour from golden yellow to dark red. (*Vide* fig. 3.)

The carnallit is very deliquescent, and on exposure to a damp atmosphere the chloride of magnesium gradually drains away, leaving the chloride of potassium behind. This probably accounts for the presence of sylvin or pure chloride of potassium, small quantities of which are found underneath the carnallit. It is rather more abundant in the Anhalt mine; and this would further tend to prove the theory that it is the product of the decomposition of carnallit, as the chloride of magnesium is found to preponderate in the lower-lying level of the Stassfurt mine as *tachydrit*.

Sylvin is variously coloured, and has a bright shining appearance, which has been not inaptly compared to mother-of-pearl. Its specific gravity is 2·025, and 34·5 parts of it dissolve in 100 of water at 18$\frac{3}{4}$° C.

It is occasionally found in large perfectly transparent crystals, which, according to Professor S. Magnus of Berlin, are as transparent to heat as rock salt; and this diathermic property does not change with the temperature of the source of heat any more than rock salt does, and which has hitherto been the only substance known to possess the latter quality.

The *tachydrit* already mentioned is a salt having the same composition as carnallit, but in which the potassium is replaced by calcium, its formula being $Ca\,Cl_2 + 2\,Mg\,Cl_2 + 12\,H_2O$. It is very deliquescent and very soluble, 100 parts of water at 18$\frac{3}{4}$° C. dissolving 160·3 parts of the salt. It is the only salt which raises the temperature of the water during solution, all the others having the property of lowering it during that operation.

The Salt Deposits at Stassfurt.

Fig 1.

Section of the Strata between Stassfurt and Schonebeck

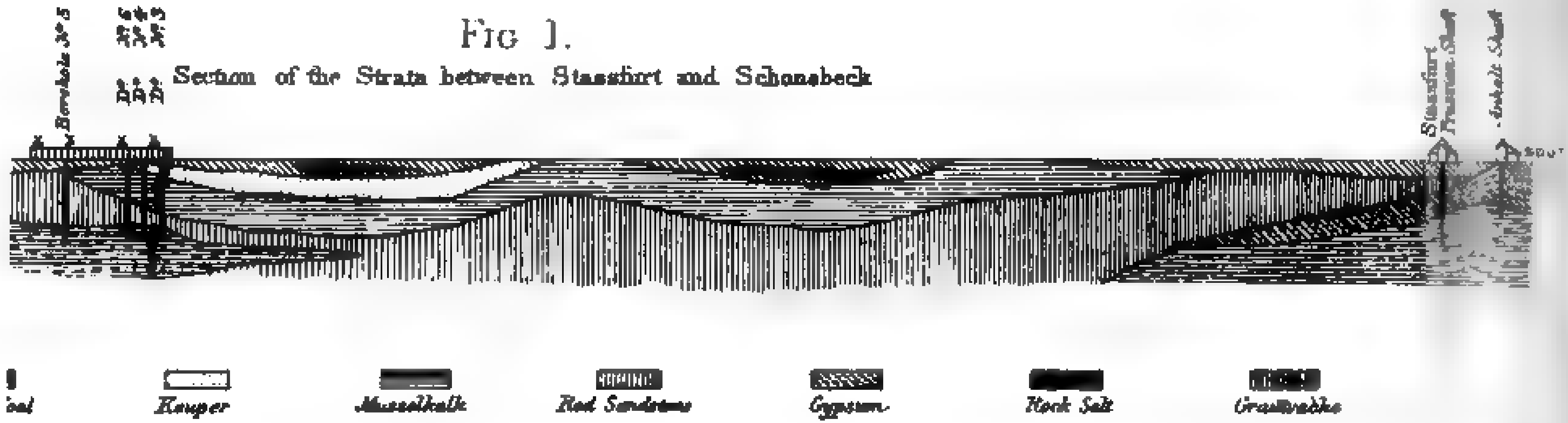


Fig 2.

at the Stassfurt Shafts

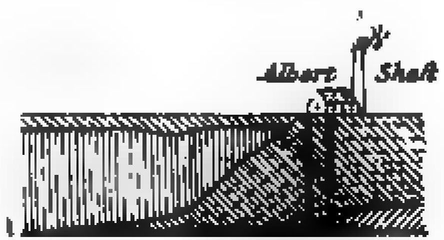
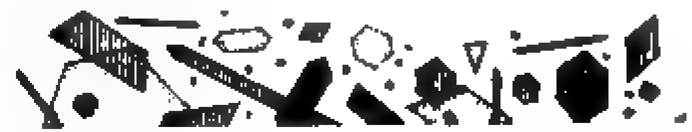


Fig 3

Crystals of Eisenglimmer from Carnallit. (Magnified)



Besides sylvin and tachydrit, there exists also, though in such irregular quantities that it cannot be calculated upon with certainty, a salt called kianit, having the following composition:—

$$Mg\ S\ O_4 + K_2\ S\ O_4 + H_2\ O.$$

It is evidently the product of a secondary decomposition, arising from the action, probably during a low temperature, of sulphate of magnesium upon chloride of potassium.

We also have what is probably the most peculiar and unaccountable compound in these mines, viz., boracite, the composition of which is $6\ Mg\ O, 8\ B_2\ O_3 + Mg\ C\ l_2$; specific gravity 2·9. It is found scattered all over the deposit in nodules, varying in size from the most minute up to 7 or 8 inches in diameter, and although occurring in the most soluble salt beds, is of itself almost insoluble in water, and, in fact, is with difficulty decomposed by acids; but its greatest peculiarity is, that it always, and without exception, contains a kernel of the easily soluble carnallit or tachydrit. It does not exist in any great quantity, the annual yield being somewhere about 10 tons. A small quantity of bromine is also found in this region, existing as bromide of magnesium; cæsium and rubidium can also be detected; but hitherto all attempts to prove the presence of either lithium or iodine have been without success.

The ingredients in this region do not exist as a homogeneous mass, but are deposited in distinct layers, which repeat themselves frequently, and vary in thickness from a mere line to several feet.

It is from the impure carnallit that the manufacture of muriate of potash is so largely carried on in the neighbourhood. This salt, which is coarsely ground at the mines, has an average composition of—

Chloride of Potassium,	16
Chloride of Magnesium,	20
Chloride of Sodium,	25
Sulphate of Magnesia,	10
Water,	29
	100

It also contains small quantities of sulphate of lime and bituminous matter, which occasion the manufacturer some considerable trouble, as in strong solutions they are light and flocculent, and consequently somewhat difficult to settle.

The manufacture of the muriate is entirely a question of the solubilities of the various salts, the key to which is the fact that the double salt of chloride of potassium and magnesium forms only from

solutions containing exactly double the quantity of chloride of magnesium which exists in the carnallit. You will find it stated by various authorities that the "carnallit crystallises only from solutions containing a large excess of chloride of magnesium;" but this has been proven by experiment to be a definite chemical quantity, viz., 4 parts of chloride of magnesium and 1 part of chloride of potassium, or, in other words, 2 parts of chloride of magnesium hold in solution, up to a certain strength, 1 part of carnallit—so that on dissolving the crude salt in water, the chloride of magnesium takes up its quantity of chloride of potassium, whilst the remainder crystallises out as muriate, mixed with common salt and a small quantity of sulphate of magnesia. The mother liquors are then further boiled down to obtain a crop of artificial carnallit, which in turn is treated in a similar manner to the raw salt to obtain a further supply of muriate. The muriates produced vary in strength from 75 to 98 per cent.

The bromine is extracted in marketable quantities; and epsom salts are also prepared at some of the works from the kieserit; whilst at others a considerable quantity of the double sulphate of magnesium and potassium—a compound containing 1 equivalent of each of the sulphates combined with 6 atoms of water—is made.

This salt is largely used as a manure for the sugar beet. It is generally understood that the beet grows equally well with soda as with potash; but the cultivators prefer to use the latter, as it is nearly all recovered in the state of carbonate, and of course is greatly enhanced in value; the beet plant being thus made to play as it were the part of the decomposing and balling furnaces, used in the ordinary course of alkali manufacture.

This leads us to consider what would have been the present state of the potash trade had it not been for the opportune discovery of this deposit, previous to which our only sources of potash were the muriate and sulphate from kelp, principally wrought in Glasgow and the north of Ireland; and the carbonate or potashes of North America. Whether the supply has regulated the demand or not, it is difficult to say; but it is a fact that the produce from the two last-named sources has rather increased than decreased, whilst we have in addition the large supply obtained from the Stassfurt deposits.

This, of course, has been followed by a corresponding reduction in price. Muriates of 80 per cent., which in 1863 sold at £21, 10*s*. per ton, can now (1869) be purchased for £8, 10*s*.

The carbonate has not fallen in the same ratio, owing to the increasing employment of it in the arts and manufactures. There is

consequently a great prize in store for the chemist who by his ingenuity can discover some more direct process than that at present in use for the conversion into carbonate of the vast quantities of chloride stored up in these German mines.

To the scientific chemist and geologist this deposit presents a vast field well worthy of attentive study and research.

The generally accepted theory is, that it is the product of the slow evaporation of some vast ocean by a process similar to that which is at present going on in the Dead Sea, the waters of which are supposed to have already been evaporated down to 1,300 feet from their original level. If we examine an analysis of this sea, we find that it contains 6½ per cent. chloride of sodium, 1⅓ chloride of potassium, 2¾ chloride of calcium, 10½ chloride of magnesium, and about ¼ bromide of magnesium. The sulphates have almost entirely disappeared; and looking at the preponderance of the more soluble salts over the chloride of sodium, we are forced to the conclusion that there must be already deposited at its bottom a vast quantity of the latter salt.

The great salt lake of North America, and some others in the south of Russia and in Asia, which contain almost nothing but chloride of sodium, must be regarded as fresh-water lakes, which derive their saline matter from some already formed deposits of salt.

In August, 1867, the Prussian government commenced boring for salt at Sperenberg, and at the end of August last year (1868) they had penetrated to a depth of 952 feet, principally through gypsum, when they suspended operations, to admit of more powerful instruments and machinery being made. These being now supplied, the work is again going on. There is no doubt that they will reach the salt strata; and we await the result with considerable interest, to see if the potash salts exist there also.

There are others besides scientific men to whom these mines are a source of interest. To the political economist they mean an almost inexhaustible supply of the "savour of the earth,"—employment to the people, trade to the country, and pounds shillings and pence to the merchant and manufacturer. To the visitor, be he scientific or non-scientific, a visit to the mines will amply repay him for his trouble.

The appearance of the workings in the kali salt portion of the mine is no less beautiful than wonderful, and is so entirely unlike what we see in mines in this country, that we are entirely at a loss for anything to which we can compare them; and it is utterly impossible for any description to prepare the visitor for the novel sight which meets his eye when he enters these workings for the first time.

All have heard of, and many have witnessed, the wonderful grandeur of the mammoth and other caves of North America, with their unfathomable subterranean rivers, where size and form, together with the light and shade produced by the flickering torches of the guides, are what excite the wonder and admiration of the traveller. At Stassfurt we have neither the rivers nor the vast size, but we have space which, in the bowels of the earth, seems great. We have beautiful form in the sparkling irregular angles formed by the pick and the cavities left by the blast, to enhance which there is the magic charm of colour,—colours of nearly every tint in the rainbow, passing from a deep purple, through crimson, bright red, orange, and yellow, to snowy white, all in regular layers, but varying in size and arrangement, and from the angle of the dip, each layer forming an almost perfect arch. The effect is further heightened by the nodules of boracit, which have the appearance (as graphically described by one of our members who is well acquainted with the mine) of having oeen shot at random from a park of artillery, so irregularly are they scattered, and so firmly are they imbedded in what meanwhile seems to us an altogether foreign place for them.

On the occasion of our visit, after having been conducted through such a gallery as we have attempted to describe, we left the main working, and after going a few yards through a narrower passage, we found ourselves in a small chamber about 20 feet square—the preliminary opening for a new working. Underneath what is now the roof of this cavern there had been a lodgment of water, which had completely dissolved all the more soluble salts, and left the common salt and chloride of potassium in magnificent crystals of absolute purity. This formed a dome-shaped roof, which, sparkling and glistening in the light of our lamps, rivalled in beauty anything we had ever imagined of the celebrated Valley of Diamonds.

IX.—*On the Sun's Distance and Parallax.* By Mr. St. John Vincent Day, C.E.

Read before the Society, April 14, 1869.

In Modern Science.

In bringing certain considerations and facts relating to the solar distance and parallax before the Philosophical Society, there is, I

think, no occasion to enter into any extended explanation of reasons for doing so. The grandeur of all problems, whatever be the method of solution employed, pertaining to the ascertainment of the values of these two constants, which to us earth inhabitants are fundamental, so far as relates to the precision of our knowledge of the chief numerical values of the elements of the Cosmos, is generally recognized; and the importance of obtaining the length of the Earth's mean radius-vector from the Sun, within the smallest attainable limits of error, has so often been expatiated on, and of late, more especially in so many quarters, that it is unnecessary for me to repeat much of what has very justly received such wide publicity.

But without unduly hastening on to the main facts of this paper, it is as well to remind ourselves that upon the accurate determination of the solar distance and parallax depends our closeness of approach to an absolute knowledge, not only of the dimensions and mass of our own "earth-ball," but also of the Sun himself, the Moon, and all the planets. Nor is this all; for beyond our own system, other systems have been discovered to exist, so far from us that light proceeding from them occupies whole years—nay, centuries, nay, even milleniums—in travelling through space to us; and any attempt at angular measurements made from the mere Earth itself to them is impracticable, because these bodies have no sensible terrestrial parallax when attempted to be so measured; that is to say, the angle contained between two rays proceeding from these far distant suns and systems to the farthest distant points on opposite sides of our Earth, from which they can be observed, is so small, that by means even of our best angular measuring instruments we are not capable of determining it. This fact may be more apparent when we remember that the angle subtended by the semi-diameter of the Earth, touching two lines or rays proceeding from the Sun, is a quantity lying between 8" and 9" of space only; and a tolerably close determination of so very small an angle of so "ill-conditioned" a triangle has baffled the grandest efforts of astronomers ever since the age when astronomy grew up into a science with laws and methods of its own. Hence, then, we require an immensely extended base line beyond our mere earth-ball before we can approximate even to any rough knowledge of the magnitude of the stellar universe; thus we have to seek one lying outside our own sphere. And as the longer that base line is, with so much the more weight does it serve us in obtaining information regarding the dimensions of the Cosmos: therefore astronomers have chosen that particular one which has the least ratio of variation,

and the utmost range in change of station for ourselves, viz., the radius-vector of the Earth from the Sun.

In speaking, then, of this radius-vector, I must make you familiar with the fact that it is not the radius-vector of the Earth from the Sun at any particular instant of time which is meant, but the *mean* radius-vector for the whole year. By the use of so gigantic a base line, then, we are able to observe and record the positions of some of the farthest visible suns or stars which people space, and that from two points whose extreme distance apart is equal to twice the length of the Sun's mean distance from the Earth; or, in other words, we are able to observe these bodies from two points situate opposite each other in the Earth's orbit, at a distance of more than 180,000,000 of miles apart. Yet with this the differences observable are generally so minute that, after the observations are reduced, it is found, with very few exceptions, the bodies themselves are so far distant that, even with the present conditions of excellence of our observing instruments, they have no sensible parallax. In the case of fixed stars, there are only nine instances wherein their parallax has been detected; and so far as is yet known, α Centauri is nearest to us, it being affected with a parallax of $0''\cdot913$, which corresponds to a distance of 20,656,000,000,000 of miles, on a certain assumption, first of all, of what our distance from the Sun is in miles; but if that be in error by only $\frac{1}{10}$, alas! how many millions of miles is not the above stellar statement also in error!

This evening, however, we have not to deal with facts and figures so far distant from and transcendental over us; and I have merely cited the foregoing remarks to lead up our minds to some idea of the significance of the subject under our consideration. Let us, then, return to the quantities nearer home, and to the true determination of which we have some more positive need and higher demand upon our care at the present time.

An unusual amount of interest is being felt in the Sun's distance and parallax at the present time, because, amongst other reasons, we are gradually approaching two of those rare astronomical events which until very lately, and for more than a century past, have been looked upon by astronomers as affording the best foundation for observations on which to compute the numerical constants—viz., the transits of Venus across the disc of the Sun, which will occur in 1874 and 1882.

It is this very year, exactly a century since, the last transit of Venus occurred, and was observed largely on account of attention having been directed to the employment of the method, as the best

possible basis for solar distance observations, by the illustrious British astronomer Halley. I need scarcely remind you of the interest which the leading European nations of that epoch took in observing the transit. Expeditions were fitted out to the southern hemisphere and the Pacific Ocean by the British Crown, whilst France, Russia, and other Continental powers followed her example in their respective regions of empire; the result being the formation of a vast collection of observations from various points of the earth in both the northern and southern hemispheres; and from the most inclement plains of snow-covered Siberia to the waving palms, sunny shores, and coral islets of our gallant Captain Cooke's Otaheite.

The method of observation by means of the transit of Venus consists in noting the times of ingress and egress of the planet on the Sun's disc from as many pre-selected stations on the Earth as possible (and whose longitude must be well known), from which the whole transit is visible; after which the observations have to be reduced by complex mathematical methods, involving much faithful labour and due application of corrections for errors, which, through various inseparable physical and personal causes, creep into the observations.

I have alluded to the ingress and egress of the planet; but I have not mentioned a special difficulty which attends the observing of this with accuracy.

As soon as the planet begins its journey fairly across the Sun's disc—that is to say, at the instant when the outer edge is in contact with the Sun's limb—it does not appear as a round black ball projected on the luminous solar disc, but for a time the two limbs appear to be joined together by a black-looking protuberance or ligament; and until this breaks the planet is not seen to be fairly off on its transit across the Sun; indeed, during the whole of the time that it is passing on to the Sun its entire circumference appears in an agitated, tremulous state, so that the exact moment of ingress or true contact has until lately been a matter of much uncertainty.

A similar order of appearances present themselves at the opposite limb of the solar disc when the planet is about to egress. For a very long period it has been a subject of much speculation as to what is the cause of the formation of the black-looking ligament; but it is now generally with confidence ascribed to *irradiation*. The older astronomers who discussed the observations of the transit of 1769, it appears, did not allow for these irradiation effects, or, in other words, make sufficient distinction between the time of *real* and *apparent* contact, which, from this protruding appearance, they failed to

eliminate, and considerable error, thereby *partly* caused, crept into these discussions; whence all the results deduced from this series of observations have, until the more recent ones by Powalky, in 1864, and Stone, in 1867, resulted in values for the solar distance which more modern methods have shown to be too large. But we are not even yet quite safe from observational uncertainties of that order, all arising from the excessive brilliancy of that wondrous solar disc,—a brilliancy which we cannot blame when human energies depend so entirely upon it, but a most troublesome brilliancy to the optical observer; for it has been asserted by the highest authorities, and Wolf * has recently shown, that the difficulty of obtaining the true contact of a black point on that over-bright disc arises from an imperfection of the telescope, which varies from zero upwards to any amount, according to the good or bad quality of the instrument.

Since the Venus transit of a century ago, other methods, then, have been devised for obtaining the values of the elements we have under our notice; and as it is impossible in the course of one evening to dwell at length on the special features and compare the advantages of either method, I merely mention them here. These consist, then, of three different systems, founded on observations of the planet Mars.

A. By making nearly simultaneous observations of the difference of declination between Mars and a neighbouring star by means of equatorial telescopes in opposite hemispheres of the earth. This method was employed in the United States astronomical expedition to Chili. It was again proposed by Captain Gilliss in 1862; and observations in this way were made at Upsala, Leiden, and at Washington in the northern, and at Santiago in the southern hemisphere.†

B. By similar observations with a meridian circle, Mars being compared with a number of stars pre-selected. This method was suggested by Winnecke, and first employed in 1832 between the Greenwich, Cambridge, and Altona Observatories in the northern, and the Cape Observatory in the southern hemisphere. The discussion of these observations showed very decidedly that the solar parallax value of Encke was too small, and it thereby was raised from

$$8''\cdot5776 \text{ to } 9''\cdot028,$$

* See a paper by MM. Wolf and André in *Comptes Rendus* for January 25, 1869.

† *Vide* "Investigation of the Distance of the Sun," by Professor Simon Newcomb, published in 1867 as an appendix to the *Washington Astronomical Observations* of 1865.

and affected with a probable error less than the absolute error of the former method.

C. By differences of right ascension between Mars and neighbouring stars, when far east or far west of the meridian, and also when high up upon the meridian, as seen from a single observatory, such observations being made for a fortnight before, and a fortnight after, the planet's opposition. This plan appears to offer advantages in the following respects:—

α. That Mars may be compared with stars throughout the night.

β. That it has two observable limbs, both admitting of good observation.

γ. That it remains long in proximity to the earth.

This method was first employed by Bond at the Harvard Observatory, in 1849-50, during the opposition of that year,* and the parallax value then obtained was

$$8''{\cdot}605 \pm 0''{\cdot}4.$$

It was further employed at Greenwich in 1862, and at the Cape of Good Hope in the same year; but was found, on the whole, to fail, from the badness of the atmospheric definition when the planet was at a low altitude.

Another method of determining the Sun's distance and parallax is from the observed parallactic inequality of the Moon; but as the uncertainty of the observed value of the parallactic inequality amounts to several tenths of a second, so close an approximation to the truth by it can scarcely be expected as by the preceding methods.

A fifth foundation on which the value of the solar parallax may be determined is, by combining the lunar inequality in the motion of the Earth with the known mass of the Moon; whilst the last means of measurement devised is based on the beautiful experiments of the late M. Leon Foucault, for determining the velocity of light by means of revolving mirrors, combining his experimental data with the known value of aberration of light.†

In reviewing all the different methods which astronomy now possesses, the great question to be settled is, In which of them are

* See *Astronomical Journal*, No. 103.

† The origination of this method does not appear to be due to Foucault, but to Arago, who, in 1828, being impressed with Wheatstone's mode of measuring the velocity of electricity by means of revolving mirrors, devised a system of apparatus for experiment, and which was made by Breguet. Arago, however, does not appear to have been successful in what he tried; and it was left for Foucault to devise more suitable apparatus and deduce the results. (Vide *Cours de Physique de l'Ecole Polytechnique*, par M. Jamin.)

the errors least? and should we continue to place our trust now, and until the year 1882, in the results obtained from the last transit of Venus, in preference to what is deduced from any other method?

We must not forget that, a century ago, the art of observation was very imperfect compared to its present state; and as Professor Simon Newcomb, in writing me on the subject in February last, has truly put it,—"To me the most striking thing is the tenacity with which the old notion, that the old transits of Venus afford far the most accurate value of the solar parallax, seems to adhere to men's minds. It seems to be forgotten that micrometers have been invented, the art of combining observations discovered, and personal and instrumental errors investigated, since there was a transit of Venus." But, during the advancing age of the new methods, Mars has been so often observed that it is only reasonable to confide our faith more firmly in the results deduced from it, especially as these are to a great extent confirmed by other methods. Of course, the errors in the long-accepted solar parallax value of Encke, which the more modern methods of determining it pointed out, led some astronomers to think of re-discussing the old 1769 observations of Venus; but no one had the courage to undertake it previous to Powalky in 1864. He then effected a re-discussion, and found the parallax to be, not Encke's $8''{\cdot}5776$, but $8''{\cdot}8320 \pm 0''{\cdot}020$, or $0''{\cdot}2544$ larger than Encke's, corresponding too to a diminution of the previously accepted value of solar distance by about 3,000,000 of miles. Powalky obtained this result mainly through ascertaining the longitudes of the observing stations more accurately than they were previously known, and by excluding or rejecting many observations where such data were unprocurable. Yet now, strange to say, *because* he confined himself to those observations and data which were known accurately, a pretence has lately been set up in this country in one or two quarters that his discussion has but little weight, and may be righteously passed over in history and neglected in research. So, accordingly, it has been with him in some recent British publications; although, had he *not* excluded these observations, they would have had no other effect than to introduce a larger error into the final result. It is rather striking to note the migrations of the wave of opinion in this country, for only quite recently (within the last four months, in fact) fault appears to have been found with Powalky.*

* Powalky's discussion was published in 1864 as an original dissertation on receiving a doctorate at the Christian Albert University, under the title of *De Transitu Stellæ Veneris ante discum Solis, anno 1769, peracto ad Solis Parallaxim accuratius determinandum novæ disquisitiones.*

For being so unfortunate, indeed, in having done what is clearly the right thing to do, not a word was said against his work in this country until after his printed re-discussion had been honoured in France by translation into the French language and publication in the *Connaissance des Temps* for 1867. It had also been accepted in America in the same year, approved of after a special examination by Newcomb, republished and employed by him as a weighted result in his general parallax discussion for evolving what he hoped would be a standard mean for all nations, from all the values of, and all the varied methods of obtaining, the solar parallax.*

A considerable time, then, after Powalky's results had been published, and Professor Simon Newcomb's comprehensive discussions and compilations containing them had also appeared,† a British astronomer of eminent genius, Mr. E. J. Stone, of the Royal Observatory, Greenwich, re-discussed the 1769 transit observations, and brought out a parallax result of $8''\cdot910 \pm ''\cdot03$. This is slightly greater than Powalky's value, the difference of the two being $8''\cdot910 - 8''\cdot832 = 0''\cdot078$.

Mr. Stone, no doubt, has made a very excellent re-discussion, and he is entitled to receive all that is due to him for having done so; but why are Powalky's and Simon Newcomb's long previous works either so contemptuously undervalued or completely ignored by him and his

* As illustrative of Simon Newcomb's thorough appreciation that, in the midst of the modern determinations of parallax, ranging from $8''\cdot80$ to $8''\cdot95$, re-examination should be made as to how or why Encke's result, in 1824, from the Venus observations of 1769, usually reputed to be the best method, had given so erroneous a quantity as $8''\cdot5776$; and also that he, Simon Newcomb, considered that such a re-examination had been made with sufficient ability by Powalky, I quote here the commencement of Newcomb's paper in 1867.

"About ten years since, astronomers began to suspect that Encke's value of the Sun's distance, deduced from the transits of Venus in the years 1761 and 1769, was largely in error. The different methods available for its correction all agreed in indicating a diminution of between one-twenty-fifth and one-thirtieth of the whole distance. *The last doubt of the correctness of the suspicion was removed by the publication of Powalky's paper on the transit of 1769.* In this paper it was shown that, with a more accurate knowledge of the positions of observing stations, the results of this transit agreed with those of the modern systems."

The italics are my own, and seem called for by a recent outcry in this country that Powalky's result had convinced—had influenced—no one!

† I am not certain whether Newcomb's discussion was published previous to Stone's commencement of his re-discussion; but it is quite certain that it was previous to Stone's having been made public. Indeed, Newcomb's value in solar distance was mentioned by me before this Society several months previous to the appearance of Stone's paper, and published at page 292, Volume VI., of our *Transactions.*

supporters, and his own results lauded, as if no one else than Mr. Stone would have attempted so arduous an undertaking? and that no one worthy stood between him in 1868, and Encke in 1824, in that Venus problem? The answer to this was recently delivered by the President of the Royal Astronomical Society,* and defended, on account of what I have before alluded to, namely, the rejection by Powalky, in his discussion, of some of the 1769 observations; while, as to what Simon Newcomb had done, it is boldly asserted in other quarters that he did not make a technical re-discussion, and therefore requires no notice whenever re-discussions are alluded to. Certainly, he did not make a discussion *de novo* on these Venus observations; for, after carefully examining Powalky's discussion of them, he found it so able and full that he deemed the task of competing with him unnecessary; but to show how carefully he had gone over Powalky's work, I may mention, besides referring to the foot-note on page 17, that Simon Newcomb ultimately points out the necessity of altering the final result, for a reason of his own. See section 9 of his splendid investigation, where he says, "The results of Powalky's discussion will be accepted. He finds $\pi = 8''\cdot832 \pm 0''\cdot021$. But considering that the longitude of the observing station at San José is uncertain, he arbitrarily changes it by 10 *s.*, which increases the parallax to $8''\cdot86$, which he considers the most probable value."

"That so small a change in the longitude of a single station should change the parallax so largely, shows that the probable error of $0''\cdot021$ must be illusory. I think $0''\cdot04$ a more likely value of this element."

Then, although Mr. Stone's result has received such unqualified distinction at home, it does not seem likely to be overrated elsewhere; for in France M. Faye, the celebrated astronomer, has revised Mr. Stone's work; and from precisely the same observations on which Mr. Stone's result is founded, deduces a parallax of $8''\cdot8$ with an error of $\pm 0''\cdot1$—*i. e.*, much nearer to Powalky, and Powalky *cum* Simon Newcomb, than to Stone. M. Faye further shows† that all we can claim from the 1769 transit observations is, that the parallax lies somewhere between $8''\cdot70$ and $8''\cdot90$; while Wolf, in the paper before alluded to, shows that Mr. Stone has assumed as *constant* a physical element which really *varies* between wide limits; so that it is really difficult to judge in what respect his discussion is one whit better than that of Powalky, his predecessor by several years, and much approved of in Paris and Washington, though not in London.

I have now, I think, put under a decidedly impartial review the

* *Monthly Notices.*

† *Comptes Rendus*, January 4, 1869.

claims, in point of time and importance, of the most recent work which has been executed in reference to the evolution of more accurate values of the solar parallax, and therefore proceed to the second part of this paper, namely,

The Sun's Distance in History.

Before pointing out wherein the most probable value of the Sun's distance and parallax lie, it is not only particularly interesting, but I hope hereafter to show how useful and important, under a truthful view of the original enlightenment of our race—nay, it indeed behoves us to inquire if any record exists of the Sun's mean distance other than what has been commonly collected together in history; whether, for instance, any index is to be found planted on this earth in early primeval ages, at once yielding a more perfect statement of the all-important distance of the material centre of light, heat, force, and animal life, regarding which a few only in those days were enlightened, and which it has taken all the observations and science since built up by man's own effort to at last approximate to. A consideration of the Sun's distance in history will afford us some clue to a verdict on this mighty question; and if any such record should be found embodied in such a manner, relatively with numerous other cosmical facts—that is to say, in proper place and order, and with noteworthy practical excellence of constructive execution—let us not pass over it hurriedly, though no ancient author, whether sacred or profane, has left us a written account of it; but rather let us weigh and consider, by our own scientific mensurations of the ancient stones, whether it is, or is not, so convincing that we are bound to give it a place in our collective table of results; and to extend that table upward in time towards the *origin* of mankind in order to include so precious a result.

To begin, then, with what has *hitherto*, but chiefly on Greek testimony only, been received as the earliest historic record of human thought regarding the linear value of the mean solar distance, we have to go back to the time of Herodotus, who, writing about B. C. 460, has handed down to us this, namely, that after the domination of the Gentile nations, which began B. C. 597, had proceeded for a long period with success—*i. e.*, about B. C. 500—the first dawn of thought regarding the solar distance made its appearance; and from what he states as having been the condition of knowledge at the period we are considering, namely, that the Earth was thought to be the centre and chief body of the universe, and a flat plain, whose navel or centre stone was situated at Delphi in Greece, and that the

Sun was merely a secondary, uncertain, and easily influenced body which was in some unexplained way movable about or over it, but acted upon by the same forms of force which are sensible to us as acting upon the bodies round about us here; so much so, that the Egyptians thought the Etesian winds during the winter blew the Sun southwards; and he, Herodotus, the most learned Greek of his time, agreed that that was the best and most probable explanation. Hence we may fairly judge that he did not consider the Sun to be more than 10 or 12 miles from the Earth; as we are not warranted in inferring from what we do know that any strong winds prevail at a greater distance from the Earth's surface. Not long after we find, indeed, the Grecian ideas expanding; for Anaxagoras, the son of Hegesibulus, asserted *the real size of the Sun to be as large as the Peloponnesus,* and such a real size, combined with the known angular subtense of the Sun in modern times, may be taken as indicating a distance of 14,000 miles. While another century gave yet a further increase, and an immense one, to Grecian conceptions of cosmical space, by the only true method too, or an attempted angular measure, of a definite and pertinent problem; for, about B. C. 280, Aristarchus, the astronomer of Samos, concluded, by measures of the Moon's dichotomy, that the solar distance was so huge as 5,300,000 + 4,610 = 5,304,610 British miles $\pm$ 200,000.

Such was the growth of human school ideas as to the length of the Sun's distance, down to the Christian era; and thus it remained for some time afterwards, or up to the period, indeed, when the famous Alexandrian astronomer and mathematician, Claudius Ptolemy, shone before the world.

In A. D. 140 he came to differ with the co-efficient of Aristarchus, which he thought too great; but adopting the lunar parallax value of Hipparchus, he concluded the sun's distance to be 5,280,000 $\pm$ 500,000 British miles, and therefore

$$\pi = 3'.$$

Kepler, about 1620 A. D., deduced from his own researches and computations, made on Tycho Brahe's observations of Mars, that the Sun's distance was

26,400,000 British miles;

and affected with a probable error of

+ 13,000 − 9,000.

In 1750, De La Caille observed the opposition of Mars at the Cape of Good Hope—it being observed by others simultaneously in Europe—and concluded the distance at

81,650,000 British miles $\pm$ 4,000,000,

corresponding to

$$\varpi = 10''.$$

Having thus shortly traced the historically recorded human assumptions, or efforts of the schools, regarding the numerical values of these elements of the Cosmos, we approach the year 1769 A. D., the period during which, and in view of the non-advanced state of that era, were obtained what have until lately been on all hands considered the only reliable observations on which the values of these elements could be most closely approximated; and the result thus far of our investigation is, that man's thought in regard to the length of the Sun's distance had advanced during a period of 2,229 years from about 10 to 81,650,000 miles.

The 1769 observations were reduced and discussed twenty years after they were made, or in 1789, by the famous French astronomer Delambre; and he found the Sun's distance

96,100,000 British miles $\pm$ 1,000,000,

and $\varpi = 8''\cdot5$ to $8''\cdot7$ = mean value $8''\cdot6$.

In 1824, it was suspected pretty generally, from further discussions of the 1769 transit observations, that the values deduced therefrom by Delambre were a little too great; accordingly, the value of distance was reduced to

95,000,000 British miles $\pm$ 800,000.

In 1832 Mars was again in opposition; and the late Astronomer-Royal for Scotland, Professor Henderson, who at that time was resident at the Cape Observatory, observed it. From these observations he was led to conclude that the then assumed solar distance and parallax values needed further reduction; and he placed the former at

89,580,000 British miles $\pm$ 500,000.

$$\varrho = 3962\cdot7.$$

$$\varpi = 9''\cdot125.$$

Since this period Mars has been several times in opposition, and duly observed; at the same time, there has been no lack of labourers in the field of computations based thereon; so that without at present particularly noticing each individual case, I may mention that between 1862 and 1863 Mr. E. J. Stone, of Greenwich, whom I have had occasion to previously mention, gave out the value of the Sun's distance from this source as

91,678,000 British miles $\pm$ 2,000,000;

and he assumed

$$\varrho = 3962\cdot7;$$

therefore

$$\varpi = 8''\cdot915.$$

I should here state that previous to Stone's announcement, Winnecke had, by his system of comparing Mars with a number of pre-selected stars, deduced

$$d = 91{,}184{,}000 \text{ British miles;}$$

and

$$\pi = 8''\cdot964.$$

At the same period another method of ascertaining the constants we are considering was being worked out, namely, by means of the experiments of the late M. Leon Foucault on the velocity of the transmission of light, also explained in the previous part of this paper, and which showed probabilities that the true value of

$$d \text{ was } 92{,}254{,}000 \pm 154{,}000,$$

$$\pi = 8''\cdot86;$$

and in 1864 and 1867 Powalky and Simon Newcomb respectively published their exhaustive discussions; with what results, as well as the subsequent labours of Stone, Faye, and Wolf, the first division of the paper shows.

TABLE I.

Name.	Date.	Method.	π	d
Bond, . .	1849-50	γ Mars.	8″·605	π = 8,600, corresponding to d = 95,043,000
Ferguson, .	1863	β Mars. 15 Observations, 1862, Albany, U.S.	8″·611	
Faye, . . .	1869	Venus. Observations, 1769.	8″·8	92,883,000
Newcomb, .	1867?	Lunar Equation of Earth.	8″·809	92,788,000
Powalky, .	1864	Venus, 1769, re-discussed.	8″·832	92,550,000
Ferguson, .	1863	β Mars. 12 Observations, 1862, Washington and Santiago.	8″·834	92,525,000
Newcomb, .	1867	Parallactic Inequality of Moon.	8″·838	92,484,000
Hall, . . .	1863	α Mars.	8″·842	92,442,000
Delaunay, .	?	?	8″·85	
Hansen, corrected by Newcomb, .	1867	β Mars. About 100 Observations, 1862, re-discussed.	8″·855	92,306,000
Foucault, .	1862	Velocity and Aberration of Light.	8″·860	92,254,000
Newcomb, .	1867	General Mean.	8″·860	

TABLE II.

Name.	Date.	Method.	π	d
Winnecke, .	1863?	β Mars. 26 Observations, 1862, Pulkova and Cape.	8"·964	91,184,000
Le Verrier, .	1862?	Physical Astronomy. Investigations of Sun, 1858; Theory of Venus, 1861; and Theory of Mars, 1862.	8"·95	91,326,306·14
Stone, . .	1863?	β Mars. 58 Observations, Greenwich and Cape, 1862.	8"·943	91,398,000
Hansen, . .	1864	Parallactic Inequality of Moon.	8"·916	91,675,000
Stone, . .	1868	Venus, 1769, re-discussed.	8"·910	91,736,000

I have not thought it necessary to allude *seriatim* to other labourers, such as Le Verrier, Delaunay, Ferguson, and Hansen, because their results will now follow in the order of their different values of the solar parallax, according to the preceding tables.

NOTE.—In the foregoing references and tables, π represents the Sun's parallax in seconds; d, distance from Earth in British statute miles; ρ, Earth's radius assumed in the discussions.

We see, then, at a glance at these two tables, that in the first all the values, except the two first given, crowd about a parallax of

$$8''{\cdot}8 + x; \text{ } x \text{ being a quantity varying between the limits of } 0''{\cdot}009 \text{ and } 0''{\cdot}060.$$

In the second table the parallax values crowd about

$$8''{\cdot}9 + x,$$

x in this case varying between the limits of 0"·064 and 0"·010.

We also find in both tables that, from observations made on the same planet (Mars) at the same period, different computers obtain different results, which again differ from values obtained from other data. Hence the solar parallax discussers are divided into two groups, or even hostile armies,—one, who declare for 8"·9 + something, and the other, who uphold 8"·8 + something; and they wage a dire war of words and figures against each other, combating each other's work to the uttermost, and ignoring them, if they can, in history; while each avows that *his* group does really contain the truth so much sought after, and that it is nowhere else than there in that one result group. Certainly not *between* the two rival groups, they each say; and yet why should it not be there,

seeing that there extends between the two a broad sort of neutral ground, extending from parallax 8"·910 to parallax 8"·860, and right in the middle of which space an unbiassed mathematical mean of all the results of all the observers will be found to locate itself. Such, however, is the bitter strife of the combatants on either side, that they will allow anything rather than the results of their opponents to take a rank in the mean equal to their own; and hence they can neither come into that middle neutral ground themselves, nor will they allow any one else to come there. They dead-lock the whole affair as regards themselves or their contemporaries; but assist involuntarily in making out a more remarkable case for what we shall presently find has been occupying the very centre of that debatable ground of modern science ever since the beginning of the history of man upon earth.

Now, it is not my desire to promulgate views which to some members of the Philosophical Society may be unacceptable; yet, rather than conclude the present paper with the unsatisfactory picture of combatants being left fighting, and with no apparent prospect of one party ever getting completely the better of the other, it is my duty to direct attention to another as totally independent testimony to the numerical value of the solar parallax; and which, from its numerical quantity, *is* evidently in possession of the ground, though how it originally got there, it may be difficult indeed to tell.

In the course of last session it will be remembered that I read before this Society a paper on some points in the theory and facts of the Great Pyramid, and at the same time presented an appendix to it by Mr. Petrie on his so-called Pyramid Sun's distance. Mr. Petrie, in 1867, when investigating, as he is now pretty widely known to have done, and that very extensively, the symbol system and marked references of the Great Pyramid, to, amongst other and more weighty things, certain cosmical data, showed from it that the Sun's parallax was

8"·87548,

which corresponds to a radius-vector of

92,093,000 miles.

It is right for me to explain that Mr. Petrie's investigation in this country, and Simon Newcomb's in America, the results of which so closely accord, were carried on simultaneously and independently, without one knowing what the other was doing. Both were published long prior to Mr. Stone's discussion of the Venus observations of 1769; but the most remarkable feature in the whole matter is, that

this Pyramid distance and parallax lies exactly in the narrow ground disputed by the two grand armies of observers and computers, who combat each for their own being the true parallax, deduced and deducible by the methods of modern science from observations of nature. Seeing, then, how very uncertain is the unknown quantity in dispute between the two parties, we should be only adopting the generally acknowledged method in modern times of striking means, if we suggested that the truth lies just between the two limits set by the tussles of these opposing hosts. If so, then, unacceptable as it may to some appear, the Pyramid value occupies that position, and has occupied it for the last 4,000 years. On that throne of centuries it had, after 1,500 years, looked down on the early efforts of the first Greeks to solve the problem, wept over their first petty estimates of 10 to 10,000 miles, approved of their advance to 5,000,000; but had to wait the characteristic period of forty centuries before mankind had made any effectual approach to the grandeur of truth as it is in nature, or as it was marked in early patriarchal times, in that earliest, most unique, most scientific building that the whole world has to show, either in Asia, Africa, Europe, America, or Polynesia.

Call this occurrence, then, what you please—call it chance, remarkable coincidence, or apply any other epithet you like—but taking it merely as a coincidence, is it not astonishing that it should only have made its appearance just at the time when (and not before) the values of the Sun's distance and parallax, deduced by modern science, are approaching so close to each other that there is barely a difference between them—at a time when the closeness of agreement from different methods point out the advanced perfection of each?

But one word more. I wish it to be understood that I would not come before you with such a reference if the coincidence, as such, stood alone—even so, as then, it would have nothing convincing about it; but this coincidence is regularly and orderly linked in with so many others in the same building, and which agree so closely to the best ascertained values of cosmical elements, that it appears impossible to avoid the conclusion, under the shadow of its long-hidden testimony, that there was *intention* in the coincidence; also, that the Pyramid was by some instructed hand placed on the earth in remote primeval ages, not so much to serve any immediate purpose of prime importance, but to remain there fixed on its foundation, and stand forth as a protesting witness in these later times, either to the falsity or truth of man's conclusions regarding those sublime realities, facts, figures, and immensities of the universe, the certainties of which can alone be visible to the Creator himself. If so, then, additional force is lent to

the legend of all ages—that the Great Pyramid pre-eminently referred to Sun and Earth.

X.—*Recent Researches into the Post-tertiary Geology of Scotland.* By Rev. Henry W. Crosskey, F.G.S.

Read before the Society, December 7, 1868.

In the earlier researches into the Post-tertiary Beds of Scotland, two superficial deposits alone were noted. The lowest was vaguely termed "Till—a stiff unstratified clay, mixed with boulders;" the upper was described as brick, or finely laminated clay overlaid by sand and gravel. The whole of the fossils found were classed together, and catalogued as "Shells from the newer pliocene deposits in the British Islands."

Mr. Smith of Jordanhill, however, discovered a geological epoch when he detected the fact that two distinct faunas had been confounded together, and discriminated the "*Glacial Deposits*" of Great Britain and Ireland from the "Raised Beaches." "A Glacial Epoch" was thus added by Mr. Smith to the geological record; and in connection with the study of its phenomena his name ought always to be honourably remembered, and the results of his researches acknowledged.

Mr. Smith's papers have been collected together, and indicate the successive steps taken by his mind towards his great discovery. They thus constitute a chapter in the history of geology of great value and interest; and are not intended to present any summary of final results.*

Mr. Smith gives a catalogue of "Marine Testacea, including Cirripedia, Annelida, and Foraminifera," from the glacial deposits of Great Britain and Ireland, which includes 196 species. This catalogue, however, presents many difficulties.

There are several "*new species*" recorded; but, unfortunately, the original specimens from which these were described cannot now be found; so that it is impossible to say whether some of them may not be identical with the varieties of modern conchologists.

Considerable perplexity arises also from the innumerable synonyms

* *Researches in Newer Pliocene and Post-tertiary Geology,* by James Smith, F.R.S., Glasgow; John Gray.

borne by many of the shells catalogued; while the localities affixed are often too vague for identification.

Upon these earlier researches, therefore, many corrections and additions require to be made; and the papers of Mr. Geikie and Mr. Jamieson have added largely to our knowledge of the post-tertiary geology of Scotland.

For catalogues of newly discovered species and detailed descriptions I may also refer to a series of papers by Mr. David Robertson and myself, now appearing in the *Transactions of the Geological Society of Glasgow.* In my present communication I shall not touch upon the ground those papers occupy, but propose to point out some general questions of geological interest.

I. It is essential for any accurate investigations of the post-tertiary beds that distinct lists should be prepared of the fossil fauna of each separate locality.

The shells of distinct periods are often confusedly mixed in the same field. There is a bed, *e. g.*, which may be termed the *Pecten maximus* bed. Both *Pecten maximus* and *Ostrea edulis* occur in it of large size, and in great abundance. The size of the specimens is indeed far greater than the average of living examples in the Firth of Clyde. Its real position is *above* the arctic shell clay. It occurs in many localities at about half-tide mark. In all the coast beds, however, through the denuding action of the sea, the older deposit is exposed in apparently the uppermost position. Walking seaward from the shore, the boulder clay is first met with, exposed by the tide; then the laminated clay; then the shell clay; and finally the *Pecten maximus* sand. The true order of deposit is the reverse of this. The section along the western shore generally, commencing at the lower bed, is—

1. Boulder clay.
2. Laminated clay (no shells, but a few foraminifera).
3. Arctic shell clay.
4. Clay and sand with *Pecten maximus, Ostrea edulis,* and *Lutraria elliptica.*

At one point the arctic shell clay and the *Pecten maximus* sand come into close contact with each other, so that the fossils of the two deposits may be collected together.

Many catalogues and collections of the Clyde glacial fauna have thus included shells far more recent than the arctic period.

The collection in the British Museum contains shells which are not glacial, and which have been derived from this upper bed.

At Fairlie the two beds are both well developed; and the ground

having been dug and re-dug many times by collectors, the natural difficulties of discrimination are increased, and very little reliance can be placed upon the precise accuracy of catalogues based upon specimens from that locality. Recent shells have indeed been included in the débris of the various diggings, and have thence made their way into collections and catalogues of so-called fossil species.

Many generalizations, therefore, resting upon the published lists of glacial species, can scarcely be relied upon. It has become necessary to re-discover every shell, and to compile catalogues for each separate bed.

Until this work is finished it will be impossible to arrive at any valid conclusions regarding the distribution of species during the glacial epoch and the subsequent climatic changes.

II. It is also necessary that "*Boulder clays*" should be discriminated from each other.

"Boulder clay" was originally a term applied to the whole series of beds in which the shells occur. The shells were described as belonging to the "*Till*," whether they were found in the boulder clay itself, or in clays decidedly superior to it.

The deposits loosely termed "*Boulder clays*," however, have had more than one origin.

Any clay containing boulders is *not* identical with the old boulder clay of Scotland.

The shell clay may contain boulders, and yet cannot be termed "boulder clay" without the extremest and most deceptive confusion in the use of terms.

Boulders have been in all probability dropped into the shell clay from ice, floating over the Firth of Clyde, as they are dropped from the ice floating at the present day in the St. Lawrence; and this shell clay into which the boulders fell may have been resting upon the old "boulder clay," and have been formed long subsequently to its deposition, and by entirely different agencies.

A "boulder clay" may have been carried from the land into the sea by a glacier, and thus have covered littoral shell clays, and have become mixed with fragments of shells, although not itself of marine origin.

There is, moreover, a very marked *upper boulder clay* as well as a lower. The stones are less angular, and their polish is less fine. They have been exposed to wear and tear of air and water. The matrix in which they occur is far looser, and more sandy and earthy.

This upper boulder clay may contain even larger and heavier blocks than the lower—blocks such as might have been carried by floating ice.

The upper boulder clay and lower boulder clay may sometimes be seen in contact with each other, the shell bed having been eliminated.

Occasionally the shell bed may be seen in position between the two. This is the case at Lag, near Arran, which I examined in company with Dr. Bryce. A casual investigation might lead to the conclusion that the shells are in the boulder clay. They really occur, however, in a bed between the two characteristic boulder clays.*

An accurate classification of boulder clays, therefore, is absolutely necessary before any satisfactory theories of their origin can be established.

III. The shell clay was long supposed to be covered by an entirely unfossiliferous clay, while the laminated clay beneath it was regarded as equally unfossiliferous. The shell clay, with its abundant fauna, thus appeared to be curiously placed between an upper and an under clay, both devoid of organic remains.

Microscopic examination has revealed, however, the mistaken character of this description. Mr. Robertson and myself have discovered in the laminated clay, *Nonionina striato-punctata*, a very hardy foraminifera with a wide range of habitat; and the same foraminifera reappears in the upper clay. In the upper clay, also, we have from time to time discovered a few shells.

The laminated clay thus represents conditions highly unfavourable to molluscan life, and is either an estuarine or marine deposit.

The upper clay represents the coming on of conditions equally unfavourable to molluscan life, although probably from a different cause.

In the case of the laminated clay, which rests upon the boulder clay, we are nearer to the epoch of intense cold; in the upper clay, we are nearer to the restriction of the Clyde estuary, under a more moderate temperature.

In the one case, molluscan life might be interfered with by the rapid waters issuing from beneath snow and ice, and carrying down fine mud into the sea; in the other case, the deep marine fauna of the glacial epoch would be checked in its development by the body of fresh water brought into the estuary under circumstances more analogous to those existing at the present day.

It becomes essential, therefore, no longer to dismiss the upper and lower parts of the clay bed as unfossiliferous, but to study microscopically the clays at different heights in the same section.

* See paper "On Boulder Clay," by the present writer, in the *Transactions of the Geological Society of Glasgow*, vol. iii., p. 149; also Dr. Bryce's *Geology of Arran.*

IV. The shell beds of the glacial epoch itself need to be separately studied and catalogued.

(1.) They represent differences of depth, some being littoral, and others deep sea.

(2.) They contain sometimes a mixture of deep sea and littoral species, telling its own tales of tides and changing currents.

(3.) Generally in the western beds the shells occur *in situ;* but sometimes they are fragmentary; and this fact must also have its meaning.

The broken shells in the cutting near Drymen, *e. g.*, are precisely similar to those found at Moel Tryffaen. The eye could detect no difference between specimens from either locality; and the species are nearly the same.

(4.) Shell beds of the glacial epoch may not be precisely of the same age. The beds at the higher levels are probably older than those at the lower. The Jordanhill shell beds, *e. g.*, are probably older than the Dalmuir and Paisley deposits. There are physical reasons for believing that Jordanhill must have been elevated before the Dalmuir shell bed was deposited. The different levels at which the shell beds rest have, however, yet to be connected with the epochs at which the various elevations of the earth's crust took place in Scotland.

V. A few suggestions may be made regarding the classification of the post-tertiary beds in Scotland. They may approximately be arranged under the following classes:—

Class First.—The beds beneath the boulder clay, and which *have no boulder clay for their base.*

(1.) Mr. Jamieson has discovered fragments of shells, undoubtedly crag, in this position in Aberdeenshire.

(2.) At Kilmaurs shell beds have been recently discovered by Mr. Robert Craig *beneath the boulder clay*, which are of the common glacial character.

The deposits which are beneath the boulder clay, and have no boulder clay for their base, do not therefore belong to one period. They may be crag, they may be glacial.

At Kilmaurs, the boulder clay has probably been carried down by land ice to the sea, and thrown over the shell bed of the period.

(3.) A series of pre-glacial beds (but not "crag" in character) will, in all likelihood, be disclosed as discoveries advance. The beds at Kilmaurs, containing remains of Elephas primigenius, and corresponding beds at Chappel-hall, belong to this class.

Three subdivisions, therefore, may be brought under the first class

of beds. (1.) "Crag" beds. (2.) Pre-glacial beds, although not "crag" in any recognized sense of the term. (3.) Ordinary glacial beds. All these distinct deposits may occur *under boulder clay*, and have no boulder clay for their base.

Class Second.—Beds intercalated between masses of boulder clay.

Deposits of sand occur between masses of boulder clay of variable extent; but, so far as present investigations extend, these are devoid of organic remains. The Crofthead laminated clay contains, indeed, Bos primigenius, fresh water entomostraca, insects, and diatomacea; but it is still matter of controversy whether it was really covered by an old boulder clay, or whether the covering, in those parts in which it remains, is not a comparatively recent wash from an older deposit.*

I know no other, even alleged, instance of a fossiliferous bed intercalated between masses of boulder clay.

There is no proof yet forthcoming that any of the glacial shell beds were ever covered by boulder clay, except under local circumstances (such as those already described at Stevenston) which do not constitute any real deviation from the general rule.

1. The shell beds are often directly succeeded by the *cardium edule* bed of a more modern period, without any intervening boulder clay.

2. They are deposited in hollows of the boulder clay, and have thus been subsequent to extensive denudations of that deposit.

3. They contain large boulders not connected with the causes which produced boulder clay, but dropped upon existing sea bottoms, full of marine life.

Class Third.—The fossiliferous boulder clays. The fossiliferous boulder clays may be of precisely the same age as the shell beds which, in the other localities, rest in hollows of unfossiliferous boulder clay.

They have several peculiarities.

1. They occur universally (so far as we yet know) *near the coast.* They generally form low cliffs immediately on the shore.

2. The shells are generally broken, and very seldom, indeed, perfect. Even when perfect, they are not found in their natural living position, as is the case with the shells in the larger part of Scotch glacial clays.

3. The fauna is mixed in character. Foraminifera, *e. g.*, are found in the Caithness boulder clays, derived from the chalk masses they contain, having evidently been washed out from them. Mollusca belonging to different depths are also intermingled.

4. The fauna is sometimes even less arctic in character than that

* See communications from Mr. J. Geikie and Mr. Craig, *Geological Magazine*, 1868.

of the glacial clay, which rests upon the old boulder clay; and thus increases the suspicion that, in some instances, the so-called fossiliferous boulder clay is only a wash from an older bed.

In other cases the fossiliferous boulder clay is probably of the same age as the ordinary glacial shell clay, and indicates either the carrying down to the glacial sea of the débris accumulated by land ice, or the droppings from icebergs upon the sea bottom.

No sufficient evidence has yet been adduced to prove that the fossiliferous boulder clay is older than the ordinary glacial shell clay. It occurs abundantly on the Lancashire and Yorkshire coasts, the Irish coast, and the east coast of Scotland.

Class Fourth.—The fossiliferous glacial clays and sands, generally speaking, resting in hollows of the boulder clay.

These deposits are being described in detail by Mr. Robertson and myself, so that I need not here enter upon any examination of them.* Each locality has its own characteristic species, and differences, both of age and depth, may be detected among the beds.

Class Fifth.—Beds indicating conditions of climate possibly more genial than those which exist at the present day.

The *Pecten maximus* bed, already mentioned as being easily confounded with the glacial beds, may be quoted as affording strong indications of this character. It contains such shells as *Psammobia ferroënsis* and *Tellina incarnata*, of larger size, and in greater numbers than they at present occur, living in the neighbouring seas.

A catalogue of this bed, however, is being prepared, when further light will be cast upon this interesting point.

Mr. Jamieson has arrived at the same conclusion, from the study of the *trees* in the peat bed underlying the carse clay, with its bones of the whale, in the valley of the Forth.†

I may suggest that the *Cyrena fluminalis* bed near Hull possibly belongs to this period.

Class Sixth.—The shell beds belonging to the more recent elevations of the land, and containing species precisely the same as those now existing in the neighbouring seas, but found in slightly different proportions.

These beds may be studied in many localities—at Cumbrae, along the coast of Arran, in the banks of Irvine water. The only noticeable difference between the fossil shells and those obtained living from the sea, is in the proportions in which the different species occur, rather than in the species themselves.

VI. Another series of problems arises from a study of the relation-

* See *Transactions of the Geological Society of Glasgow.*

† *Proceedings of the Geological Society of London*, 1865, p. 185.

ships between the glacial shell beds of various localities and in different countries.

First.—Comparison between the glacial shell beds of the east and west of Scotland.

The following species of an extremely arctic character have not as yet been found in the west:—

Crenella faba.
Leda limatula.
Mesalia erosa.
Mesalia reticulata.
Thracia myopsis.
Pecten Grœnlandicus.

Leda arctica is a characteristic shell at Errol; only two specimens, however, have been found in the west—one, evidently fossil, dredged by Mr. Jeffrey, and one which was obtained from a sand bed at Stevenston.

Modiolaria discors var. lævigata is also abundant at Errol; but only the fry has been yet found in western localities.

The whole of the shells found peculiarly in the east, range within the arctic circle and off the east coast of North America, and do not live off the coast of Great Britain.

The peculiarity of the eastern beds, therefore, is their especially arctic *intensity.*

Though the percentage of species cannot yet be accurately given, there seems no doubt that upon the east of Scotland, as compared with the west, there is a preponderance of arctic and North-east American forms.

The entomostraca yield precisely the same result.

In the fossiliferous clays there are entomostraca of high arctic type that have never been found in the west, which are plentiful in the east.

The existence of an arctic current on the east, such as that which now comes over the Dogger Bank, might sufficiently, however, account for the preponderance in question.

Second.—Comparison between glacial shell beds of Scotland and England.

If the Chillesford and Bridlington beds be compared with the Moel Tryffaen beds, we have evidence of greater arctic intensity on the east of England than on the west of Wales.

At *Bridlington* we have not only many peculiarly arctic species, but the entomostraca of the Scottish eastern beds also occur; while at Moel Tryffaen, Mr. Darbishire (who has specially and thoroughly investigated the fauna) informs us that there is the present provincial association of species, though under glacial conditions and with many northern forms.

The Bridlington beds are thus, it would appear, more arctic than the Moel Tryffaen beds, precisely as the Errol and Elie beds are more arctic than the Paisley and Dalmuir beds. The relation between the fauna of the east and west, during the glacial epoch, was thus, generally speaking, the same as at the present day.

Third.—Relation of British glacial shells to living groups around the British coast.

Saxicava (*Panopæa*) *Norwegica* occurs living on the Dogger Bank in extremely deep water; but I have little doubt it was not a deep water shell off the British coasts in glacial times. I have found it in its natural boring position in the glacial clays, surrounded by many specimens of *Mya truncata*, also in their natural boring position.

The results of Mr. Jeffrey's dredging expeditions in the Hebrides are of great geological importance. Through his series of seven reports invaluable facts are recorded, which will throw great light on post-tertiary geology.

(1.) The invertebrate character of the district is chiefly northern; but for certain species peculiar to the Hebrides no locality has been recorded between that and the Mediterranean.

The fauna of the Hebrides must have obtained this characteristic subsequently to our glacial epoch.

(2.) The Hebrides constitute the southern limits of many northern species, such as *Lima elliptica*, *Leda pygmæa* (an abundant glacial fossil), *Triochus Grœnlandicus* (also abundant as a glacial fossil).

(3.) Boreal species have been dredged on the same coasts, evidently fossil, intermixed with Mediterranean and arctic species.

These facts are of great geological interest, as restraining hasty inductions from the occurrence of a few special species in the more ancient fossiliferous beds.

Fourth.—Relation of British glacial shells to the fossil fauna of the Mediterranean.

Mr. Jeffrey has pointed out that high northern shells occur fossil in the Mediterranean beds, although they do not present extreme arctic characteristics.

Pecten Islandicus, covered with a Greenland species of *Spirorbis*, was fished up in the Gulf of Naples.

Support is thus given to Forbes's theory of an open communication between the Atlantic and the Mediterranean during the glacial epoch.

Fifth.—Relation between the British glacial fauna and the glacial fauna of Canada.

The fossil glacial fauna of Canada is not so widely distinct from

the living fauna of the Gulf of St. Lawrence as the fossil glacial fauna of the Clyde beds is distinct from the living fauna of the Firth.

There are very few species in the Canadian beds which are even locally extinct.

In Scotland, however, there is a remarkable list of species, fossil in the clay, but extinct in the neighbouring seas.

Tellina Calcaria,
Saxicava Norvegica,
Astarte borealis,
Leda pernula,
„ arctica,
Pecten Islandicus,
Modiolaria discors,
Littorina limata (Loven),
Mangelia pyramidalis,
Natica affinis,
Trophon clathratus,
Velutina undata,
Cyclostrema costulatum,
Balanus cariosus,

are all found in the western clays, and are extinct in the western seas.

In the eastern beds we have in addition the following locally extinct species:—

Leda lucida.
Leda Thraciæformis
Pecten Grœnlandicus.
Thracia myopsis.
Cardium Grœnlandicum.
Scalaria Grœnlandica.

From this marked contrast of the Canadian and Scottish glacial fauna, in their relation to the fauna locally existing, it is evident that the change of climate in Scotland has been more complete than in Canada.

The Clyde glacial fossils, moreover, bear a nearer relationship to the Canadian than has hitherto been supposed.

Two-thirds (speaking generally) of the Scottish fossils have been collected in Canada.

In one section, taking Dr. Dawson's lists, out of twenty species of Lamellibranchiata, fifteen are found fossil in Scotland; and out of twenty-seven species of Gasteropoda, seventeen are also Scottish fossils.

At the period, therefore, when our glacial fauna flourished in the Scottish seas, the climate was nearly the same as that prevailing in Canada during the same epoch—*i. e.*, slightly colder than that of the St. Lawrence.

The fossils, however, must not be considered as marking the extreme point of cold reached during that epoch; but rather as indicating the commencement of slightly milder conditions than had hitherto prevailed.

The question suggested by this comparison, therefore, is, What conditions would produce in the Clyde a temperature slightly colder than that of the Gulf of St. Lawrence?

The existence of an arctic current, the wide expanse of land in the American arctic regions exercising its chilling influence, and other circumstances connected with the directions of the mountain ranges and the heights of the water-shed, account for the climate of Canada to a large extent.

A corresponding series of changes would explain *not* the whole phenomena of the glacial epoch, but the existence of the fauna of the glacial clays in Scottish waters. The shiftings of level, of which there is ample evidence, would involve re-arrangements in the relative proportions of land and water; while there would be vital alterations in the directions of the arctic currents, and a deflection in the Gulf stream.

The absence of the warm Gulf stream during the glacial epoch has been directly reduced from the cosmical theory by Mr. Croll; and the comparison between the Scotch and the Canadian beds thus adds support to his remarkable speculations.

Sixth.—Relation of the British glacial fauna to the glacial fauna of the North of Europe.

Professor Sars gives sixty-one species of mollusca, collected from twenty beds of the old glacial epoch in Norway.

Of these sixty-one species, Mr. Robertson and myself have obtained forty-eight from the glacial shell clays of Scotland. Moreover, the characteristic shells of some of the Norwegian clay beds are precisely identical with those of the Scotch. At Moss, the prevailing shell is *Leda arctica*, which is also characteristic of the Errol clay.

The climate of south-western Norway was undoubtedly more extreme than at present, during the glacial epoch; and so far as the evidence of the fauna reaches, the same severe climate extended over Scotland.

The connection between the Scotch and Norwegian fossils is indeed more intimate than the connection between the living inhabitants of the neighbouring seas; leading to the conclusion that the change of climate has been greater in Scotland than in Norway during the period intervening between the glacial epoch and the existing climate.*

In this paper I have simply sketched some points of interest for future investigations. The whole subject is so complicated, that all the theories submitted must be considered tentative; and the most dogmatic assertions are those which, in all probability, will ultimately prove the least reliable.

* See paper by the writer in the *Quarterly Review of Science*, 1868.

XI.—*On the Physical Constitution of the Sun, as revealed by the Phenomena of Solar Eclipses.* By R. Grant, M.A., LL.D., F.R.S., Professor of Astronomy and Director of the Observatory in the University of Glasgow.

Read before the Society, March 24, 1869.

The question with respect to the physical constitution of the sun is one which has naturally offered a high degree of interest to inquiring minds in all ages.

The idea entertained by the philosophers of ancient Greece respecting the sun was an extremely simple one. They supposed it to be a body having a smooth and uniform surface, to be in a state of incandescence, and to be unchangeable in all time. This was in accordance with their views of the celestial bodies generally, which they held to be totally unaffected by changes analogous to those observed on the earth's surface. It was reserved for Galileo to dispel this illusion. Turning his little telescope, the fruit of his own invention, upon the sun, he discovered that the surface of that body is diversified by irregular dark spots, which, when observed from day to day, were found to be constantly changing in form and magnitude. Furthermore, he perceived that they were all endued with an apparent motion upon the solar disc directed from east to west, and by an attentive observation of the time which they occupied in traversing the disc, combined with a due regard to the various phenomena which they presented in the course of transit, he was led to the important discovery that the sun is continually revolving upon a fixed axis, accomplishing a complete rotation in a period of somewhat more than twenty-five days. Towards the close of the seventeenth century, the elements of the sun's rotation were determined with considerable precision by Cassini.

The next step in connection with this question is due to Dr. Alexander Wilson, the first Professor of Astronomy in the University of Glasgow. By a series of attentive observations of a large spot which appeared upon the sun, towards the close of the year 1769, he was led to the conclusion that the spots are cavities in the sun's photosphere, and that the penumbra, or imperfectly luminous fringe, which is usually seen surrounding the spot, represents, in each instance, the shelving sides of the cavity. This theory of the spots

has been confirmed by subsequent observation, and is now generally adopted by astronomers. According to Sir William Herschel, the sun is composed of an opaque nucleus, encompassed by two nebulous envelopes, the lower envelope being imperfectly luminous, but capable in a high degree of reflecting the solar light; the upper envelope, or photosphere, being, on the other hand, the source of the sun's light and heat. He further shows how the various phenomena of the spots may be accounted for, by rents in one or both of the encompassing envelopes.

An important advance in the elucidation of this question is due to Schwabe, a German astronomer, who, by a persevering course of observations of the spots, extending over a great number of years, has recently discovered that the frequency of the spots upon the solar disc is characterized by a period of regular recurrence. The duration of this period has been determined to be 11·1 years. General Sabine, about the same time, found that the diurnal variations of the magnetic needle are characterized by a period of equal duration.

The most valuable collection of observations of the solar spots which has been published in recent years is due to Mr. Carrington, an eminent English astronomer. They extend from 1853 to 1861. A discussion of these observations by Mr. Carrington has led him to the conclusion that the spots have a proper motion on the sun's surface, depending in each case on the heliocentric latitude of the spot. For some years past it has been the practice at the Kew Observatory to take photographs of the sun on every day favourable for the purpose. The results, as they accumulate, cannot fail to constitute an invaluable mass of materials for researches on the solar spots.

The physical phenomena revealed during eclipses of the sun had not received much attention from astronomers until towards the middle of the present century. On the 8th of July, 1842, there occurred a total eclipse of the sun, which was visible in the north of Italy, and in the southern provinces of France, Germany, and Russia. On this occasion the attention of astronomers was, for the first time, directed to certain phenomena, which have since been found to be the invariable accompaniment of such eclipses. During the time of total obscuration there appeared around the dark body of the moon a *corona* of light, of a pale silvery colour, from the contour of which were seen to diverge long rays of light at definite intervals, suggesting a resemblance to the *glory* which painters in Catholic countries throw around the heads of saints. Furthermore, there were seen close to the dark body of the moon several rose-coloured spots, or protuberances, extending in some instances to a distance of nearly 2′ from

the moon's limb. The following are a few details of the observations made during the eclipse.

Mauvais, a French astronomer, who observed the eclipse at Perpignan, thus describes the phenomena seen during the total obscuration:—

"A few seconds after the commencement of the totality, while attempting to determine the breadth of the *corona*, I perceived a reddish point at the lower limb of the moon, which did not, however, project sensibly. Fifty-six seconds had elapsed from the total obscuration when the reddish point, to which I have referred, was seen to be transformed into two protuberances, like two contiguous mountains, perfectly defined in their outlines. Their colour was not uniform. Upon their sloping sides were seen streaks of a deeper tint. I cannot give a more exact idea of their aspect than by comparing them to the peaks of the Alps, illuminated by the setting sun, when seen afar off. One minute and ten seconds had elapsed from the total obscuration when a third mountain was perceived, to the left of the two others. It exhibited the same aspect as far as regards colour. It was flanked by some smaller peaks; but all were perfectly well defined. While this third mountain was in process of issuing forth, the first two continued all the while to increase. They attained a height which, according to my estimation, amounted to 2'. The interval between the two groups appeared to present an arc of about 25° on the moon's limb. The most considerable group—the most western in appearance—seemed to me to be a few degrees to the left of the lowest point of the moon's disc."

M. Petit states that, at Montpellier, two points first appeared at the lower part of the moon's limb: the more western before the other. They gradually, but rapidly, increased in magnitude, as well-defined objects would have done, emerging from behind the moon's disc. By actual measurement, M. Petit obtained 1′ 45″ for the angular magnitude of the largest of the luminous protuberances.

At Toulon, which was near the southern limit of the lunar shadow, Captain Bérard, of the French Marine, remarked that, during the interval of total obscuration, there was seen beyond the moon's limb, near the region where the sun was about to emerge, *a very slender red band, irregularly indented, or as it were furrowed here and there with hollows.*

At Visan, which was situate close to the northern limit of the lunar shadow, M. Guerin perceived, immediately after the total obscuration, seven or eight *very distinct indentations*, which might have been taken for so many stars of different magnitudes. They were redder, but less

brilliant, than Mars. If the whole periphery of the lunar disc had been bordered with similar luminous points, it would have presented the appearance of *a box of ebony garnished with rubies.*

M. Otto Struve has stated that, at Lipetsk, a little before the re-appearance of the sun, M. Schidlowsky perceived several rose-coloured flames, which appeared suddenly to burst out at several parts of the lunar disc. They resembled mountains, whose height, by estimation, appeared to be about 2′. *A very large part of the lunar disc was garnished with a similar reddish bordering.* M. Schidlowsky was unable to examine the entire contour of the moon, for soon after he observed the phenomenon, the sun reappeared.

M. Schumacher thus describes the appearance presented by the moon's limb immediately previous to the termination of the totality of the eclipse:—"A little before the emersion of the sun, there appeared, near that part of the lunar disc from behind which the first ray of light was about to issue, *a narrow streak of rose-coloured red light,* which extended, perhaps, over an arc of 70° or 80° along the moon's limb, and which disappeared with the *corona* and the rose-coloured mountains, as soon as the first ray of the sun darted forth."

The *corona* of light which was seen surrounding the dark body of the moon had been invariably observed during total eclipses of the sun; but the rose-coloured protuberances took astronomers by surprise, as phenomena altogether new. It has been found, however, upon consulting the records of former eclipses, that phenomena of a similar nature have been observed on many previous occasions. The following instances may be cited by way of illustration:—*

Captain Stannyan, who observed the total eclipse of 1706, at Berne, states, that *the emersion of the sun was preceded by a blood-red streak of light,* from its left limb, which continued not longer than six or seven seconds of time.

In 1733, there occurred a total eclipse of the sun, which was visible in Norway and Sweden. On this occasion several reddish spots were observed, one of which was seen to be decidedly detached from the moon's limb, as if it were a cloud floating in the lunar atmosphere.

Ferrer, a Spanish astronomer, who observed a total eclipse of the sun in 1806, states, in his account of the phenomenon, that, a few seconds before the reappearance of the sun's rays, he observed a zone to issue concentric with the sun, similar in appearance to a cloud illuminated by the sun's rays.

* The observations which follow are extracted from an extensive collection of similar observations of eclipses, which are arranged and discussed in the work by the author hereafter cited.

Phenomena of a similar nature have been observed during annular, and even partial, eclipses of the sun.

Maclaurin, in his account of the annular eclipse of 1737, states that a little before the formation of the ring, a remarkable *point or speck of pale light* appeared near the middle of the part of the moon's limb that was not yet come upon the disc of the sun, and that a *gleam of light*, more faint than this light, seemed *to be extended from it to each horn.* This phenomenon was seen about fifteen seconds previous to the projection of the whole body of the moon upon the solar disc.

Maclaurin also states that Lord Aberdour, who observed the same eclipse, remarked that a *narrow streak of a dusky red light* coloured the dark edge of the moon, immediately before the ring was completed, and after it was dissolved.

Bessel thus describes the appearance presented during the solar eclipse of May 15, 1836, which failed in a small degree to be annular at Königsberg, where that astronomer observed it, although in reality it was of the annular species :—"About twenty-five seconds before the nearest approach of the centres of the two bodies, I perceived, near the extremity of the upper cusp, a luminous point, which, without having the brightness of the sun, was very distinctly visible with the powerful heliometer. As the cusps were then approaching each other, I hoped that the annulus was about to form; but this did not happen. With respect to the point which I have just alluded to, it became more luminous. Other similar points appeared, which soon united together, and rendered visible all the portions of the moon's limb between the extremities of the cusps."

In 1850, the author of this paper undertook an investigation of the various phenomena observed during eclipses of the sun, whether total annular, or partial, as recorded in the pages of history down to, and including, the total eclipse of 1842, with the view of ascertaining what light they were capable of throwing on the physical constitution of the sun.* The following are some of the conclusions at which he arrived as the result of this inquiry :—

First, The *corona* of light seen during the total obscuration of the sun is indicative of the presence of an atmosphere about the sun.

Secondly, The red prominences are in reality solar, and not lunar, phenomena. In other words, they are appendages, not of the moon, but of the sun.

* *History of Physical Astronomy*, ch. xvii. This work originally appeared in detached parts or numbers, in connection with a scheme for the republication of the Library of Useful Knowledge Series. The first number was issued in 1848. The work was finally published complete in 1852.

Thirdly, The *sierra* of red light seen during total eclipses, immediately after the disappearance of the sun's rays, and immediately previous to their reappearance, is attributable to the existence of an *envelope of nebulous matter* which encompasses the sun, and is superposed upon the photosphere. The phenomena seen during annular and partial eclipses are similarly indicative of the same envelope.

As this last conclusion, with respect to the existence of an envelope of nebulous or gaseous matter encompassing the solar photosphere, has acquired renewed interest from recent researches in spectrum analysis, it may not be undesirable to quote the following passage, in which it was originally announced:—

"According to the usual theory of the physical constitution of the sun, that body consists of an opaque nucleus, surrounded by an atmosphere in which are suspended, at different elevations, two enveloping substances of dissimilar physical properties—the lower envelope being imperfectly luminous, but capable in a high degree of reflecting light, while, on the other hand, the upper envelope forms a resplendent canopy of clouds, which are luminous in themselves, and constitute the source of the light diffused in every direction by the sun. The observations of solar eclipses would seem to indicate, that *above* the luminiferous envelope there exists *a stratum of nebulous matter*, which is visible only by means of reflected light. Various interesting questions present themselves for solution in connection with the admitted existence of such a stratum. In the *first* place, Does *this third envelope* exercise an influence in the production of any of the other phenomena which have been disclosed by observations on the physical constitution of the sun? M. Arago has very ingeniously suggested that the solar spots which exhibit the aspect of a penumbra without a nucleus may arise from the superposition of masses of this nebulous matter above the luminiferous envelope. *Secondly*, the question arises, Does any relation subsist between this non-luminous substance, which floats in the upper regions of the solar atmosphere, and either of the other two envelopes? Sir John Herschel, in his ingenious theory of the physical origin of the solar spots, supposes a perpetual circulation to be kept up in the solar atmosphere analogous to that which, in the case of the terrestrial atmosphere, produces the phenomenon of the trade winds. Now, is it not reasonable enough to suppose that such a circulation will have the effect of continually agitating the non-luminous matter constituting the envelope nearest the solid nucleus of the sun, and throwing up masses of it above the luminiferous surface? This view of the subject, while it carries with it considerable probability, obviates the necessity of introducing into

the theory of the physical constitution of the sun the idea of a third envelope, *independent* of the two others. Future observation, prosecuted more especially with reference to the position of the solar spots during the occurrence of eclipses of the sun, can alone be expected to throw any light upon this interesting question."*

The conclusions above stated have been abundantly confirmed by the observations of solar eclipses which have occurred subsequently to 1842. In 1860 there occurred a total eclipse of the sun, which was visible in Spain, and was observed by a great number of astronomers from the different countries of Europe. It was my good fortune to observe this eclipse from an eminent position on the Sierra de Tolonio, a mountain range overlooking the valley of the Ebro. The following extract from a report of my observations, which I communicated a few weeks afterwards to the Astronomer Royal, refers to the phenomena immediately preceding the reappearance of the sun's rays:—"While I was engaged in examining the last-mentioned prominence, I perceived several other very small peaks which had just come into view, and a few seconds afterwards there was disclosed, as if by the motion of the moon, a long stratum, uniting them together at their bases, giving to the whole phenomenon the aspect of a *sierra* resting on the moon's limb, and extending over an arc of about 20°. This continuous succession of prominences was intensely red, resembling in colour the most beautiful vermilion. The light was very much condensed, there being an entire absence of the streaks which characterized the larger prominences. The reappearance of the sun was preceded by an excessively narrow band of red light, bounding the moon's limb, and connecting itself with the *sierra* previously observed. This long streak of light extended over an arc of about 25° on the moon's limb."

On the same occasion Mr. De la Rue obtained several photographs of the eclipse, which afforded a new and unmistakable proof of the red prominences being solar and not lunar appendages.

The great total eclipse of 1868, which was visible in India, will be memorable in history from the results which it has yielded in connection with the physical constitution of the sun. Spectroscopic observations of the red prominences were made in India by Major Tennant, Lieut. Herschel, M. Jannsen, and M. Rayet; and the results in every instance have indicated that the prominences are of gaseous structure, being composed mainly of hydrogen.† It may be

* *History of Physical Astronomy*, p. 400.

† A brief account was here given of the successive steps in scientific inquiry which finally resulted in Kirchhoff's great discovery, by means of which it has

here remarked that, according to Kirchhoff, the sun consists of a molten or liquid mass in a state of incandescence, surrounded by an atmosphere of a somewhat lower temperature, in which are suspended the vapours of various bodies, including iron, sodium, magnesium, barium, calcium, and several other metals.

On the day following the occurrence of the great eclipse of India, M. Jannsen succeeded in obtaining the spectrum of a prominence *in full sunlight;* and shortly afterwards Mr. Lockyer, in England, independently effected the same step. Still more recently, Mr. Huggins has been enabled, by means of an arrangement for absorbing the light at the violet end of the spectrum, to view the prominences directly, and thereby to ascertain their real form. It is right to state that the same idea for effecting this object had also occurred to Lieut. Herschel.

Spectroscopic observations made by Mr. Lockyer, during full sunshine, have independently established the existence of the gaseous envelope encompassing the sun, which a discussion of telescopic observations made during the occurrence of eclipses had already revealed. This envelope, like the red prominences which merely form the upheavings of it, has been found to consist mainly of hydrogen. From the enormous extent of these upheavings, as indicated by the observations of prominences ascending to heights of sixty, seventy, and even eighty thousand miles, it would appear that the exterior solar envelope is subject to agitations of a very tumultuous nature. Further observations may be expected to throw light on this interesting and mysterious appendage of the sun.

The President remarked that Dr. Grant, while speaking of the late striking discovery, that incandescent hydrogen existed at a vast height in the solar atmosphere, had referred incidentally to what was well known to those conversant with this subject, namely, that he had himself, seventeen years ago, suggested the probable existence of some such gaseous envelope resting on the photosphere—a sagacious conjecture only verified within these few months. He had also been the first to suggest the idea that the "rose-coloured prominences" did not belong to the lunar surface, as a lunar envelope, but to the solar atmosphere—another suggestion only verified during the most recent

become possible to ascertain the materials of which the heavenly bodies are composed. Professor Herschel, at the same time, executed some very successful experiments illustrative of the spectra of metallic flames, including an illustration of the absorption band of sodium. A paper from his pen on the subject will be found elsewhere.

eclipses. It was not a little remarkable that Dr. Wilson, who occupied Dr. Grant's Chair a hundred years ago, had been the first to propose that theory of the physical constitution of the sun which is now universally received. The name of another distinguished Professor of Glasgow University was well known in connection with solar physics; and as he was now present, the President expressed a hope that Sir William Thomson would lay before the Society his views in regard to the age of the sun and the maintenance of solar heat.

SIR WM. THOMSON said that his contribution to the meteoric theory of solar heat had been to point out that the meteoric supply could not be perennial. In his paper "On the Mechanical Energies of the Solar System" (*Transactions of the Royal Society of Edinburgh*, April, 1854), he had shown that meteors falling from extra-planetary space in sufficient abundance to generate the heat emitted from the sun for the last 2,000 years, must, by the augmentation they must have brought to the central mass, have caused a gradual shortening of the year, of which the accumulated effect during that period must have dislocated the seasons to the extent of a month and a half. But observation proves that there has been a dislocation of the seasons only to the extent of about an hour and three-quarters, since a certain eclipse of the moon was seen on March 19, 721 B. C., in Babylon. It is quite certain, therefore, that meteoric supply for sun heat has not, within historical periods, come from distant space outside the earth's orbit. He therefore found it necessary to modify the meteoric hypothesis of sun heat—a hypothesis which he had learned from a communication by Mr. Waterston to the British Association at Hull in 1853, but which he has since found had been previously proposed by Mayer. If it is true that the heat emitted by the sun is compensated from year to year by meteors, he proved that instead of a certain quantity of meteors falling in a certain time from distant extra-planetary space, as supposed by Mayer and Waterston, a double quantity in the same time must fall from orbits inside that of Mercury. But at the same time he pointed out that observation and dynamical theory of the motions of the planets must be had recourse to, to test whether or not there can be a sufficient amount of matter circulating as meteors inside the orbit of Mercury to provide sun heat for a few hundred years to come. Since that time Leverrier's fine researches on the motions of the planet Mercury give evidence of matter circulating as a great number of small planets within his orbit round the sun. But the amount of matter thus indicated is very small, probably not enough for a few hundred years' heat. It is therefore highly impro-

bable that the heat of the sun depends at all for its continuation upon a continued meteoric supply. In the present state of science, what appears most probable is Helmholtz's view, that the sun originally acquired his heat in being built up out of smaller masses falling together and generating heat by their collision, but that at present he is simply an incandescent mass cooling. In an article in *Macmillan's Magazine*, March, 1862, "On the Age of the Sun's Heat," he (Sir W. Thomson) had shown that the sun may have been in this condition for many million years, and may continue for several million future years, giving out heat and light from the vast initial supply generated in that manner; but that, without supposing the sun to be a miraculous body, continually violating the laws of matter, we cannot believe that from first to last he could illuminate the earth for several times one hundred million years, if even for so long a period as that. Since he had been asked to explain his views regarding the theory of sun heat, he took the opportunity of adverting to a statement which Professor Huxley had recently made in his inaugural address to the Geological Society of London, to the effect that he (Sir W. Thomson) had only fifteen years ago entertained a view of the origin of the sun's heat which would have "suited Hutton perfectly," inasmuch as, according to that view, the energy radiating from year to year is supplied from year to year. But Professor Huxley had not noticed the very limited supply which could possibly exist in store, according to that view, certainly not upon any estimate equal to three hundred thousand years' expenditure, and now proved to be very much less by the astronomical observations published since 1854. And, in fact, no view except Hegel's—"the motion of the heavenly bodies is not a being pulled this way and that, as is imagined (by the Newtonians); they go along, as the ancients said, like blessed gods"—could satisfy a "thoroughgoing Huttonian uniformitarian," or could fulfil the conditions imagined by Lyell as a foundation for a theory of underground heat. As to the sun, we can now go both backwards and forwards in his history, upon the principles of Newton and Joule. A large proportion of British popular geologists of the present day have been longer contented than other scientific men, to look upon the sun as Fontenelle's roses looked upon their gardener.* "Our gardener," say they, "is a very old man: within the memory of roses he is the same as he has always been; it is impossible he can ever die, or be other than he is."

* Kant's *Physische Geographie.* (Collected Works, vol. vi., Leipzig, 1839.)

MINUTES.

Corporation Gallery of Art, November 4, 1868.

THE Sixty-seventh Session of the Philosophical Society of Glasgow was opened this evening, in the West Hall of the Corporation Gallery of Art—DR. FRANCIS H. THOMSON, the President, in the Chair.

Mr. John Dalziel, Chemist, 2 Rochester Place, and Mr. Napier Smith, Glasgow Galvanizing Works, Finnieston Street, were elected members of the Society.

At the request of the Society, Mr. James Reid and Mr. William Johnston consented to act as Scrutineers of the Treasurer's Accounts.

The PRESIDENT said that as the new apartments intended for the use of the Society will not be ready for a considerable period, the Council had applied for the temporary accommodation of the Society in the Hall where they were now assembled, and which had been obtained through the kind attention of the Lord Provost, Mr. Mirrlees, Convener of the Town Council's Committee on the Corporation Buildings, Mr. Charles Heath Wilson, Curator of the Art Gallery, and Mr. William West Watson, City Chamberlain. The President proposed that the Society's thanks be communicated to these gentlemen; which was agreed to.

The PRESIDENT called the attention of the Society to the extra expense which would be required in fitting up the new rooms. This subject, he mentioned, had been under the consideration of the Council, who were of opinion that the extra outlay for furnishings should be defrayed by a subscription amongst the members, without drawing upon the ordinary income of the Society. It was estimated that Half-a-Guinea from each member would be adequate to the purpose; and the Council entertain the hope that any shortcomings in contributions of this sum will be provided against by larger subscriptions on the part of many of the members. The President having submitted this proposal to the Society, it was agreed to.

The Secretary was instructed to announce the Society's resolution in the circular convening the next meeting.

The PRESIDENT then delivered an opening address; at the close of which, on the motion of Mr. Alexander Harvey, he received the cordial thanks of the Society.

Corporation Gallery of Art, November 18, 1868.

The Society met this evening for the Sixty-seventh Annual Election of Office-bearers—DR. FRANCIS H. THOMSON in the Chair.

The following gentlemen were elected members, viz.:—

Mr. P. M. Moir, Chemist, 83 Jamaica Street; Mr. W. R. Hutton, Chemist, 77 Renfield Street; Mr. William R. W. Smith, 2 North Court, Royal Exchange; Mr. Peter Forbes, Chemist, 13 Crawford Street, Port-Dundas; Mr. George M. Gatheral, Chemist, Dalmuir Chemical Works; Mr. John Christie, Chemist, Alexandria Turkey-Red Works, Dumbartonshire; Mr. Robert Raphael, 149 West George Street; Mr. William Guthrie, Treasurer to the Water Commissioners, 23 Miller Street.

MR. JOHN MANN, the Treasurer, gave in the following Abstract of his Account:—

ABSTRACT OF TREASURER'S ACCOUNT. SESSION 1867-68.

DR.

1867.—*Nov.* 1.						
To Cash in Union Bank of Scotland,	£3	2	7			
,, Cash in Treasurer's hands,	4	12	8¼			
				£7	15	3¼
1868.—*Oct.* 31.						
To Entry Money and Dues from 22 New Members, 1867-68, at 42*s.*,	46	4	0			
,, Annual Dues from 5 Original Members, at 5*s.*,	1	5	0			
,, Annual Dues from 238 Members, at 21*s.*,	249	18	0			
,, Annual Dues from 4 Members for two years,	8	8	0			
,, Annual Dues from 1 Member for four years,	4	4	0			
				309	19	0
,, Chemical Section.—Nett Proceeds from Treasurer,				6	10	6
,, Institution of Engineers for Rent,				15	0	0
,, Interest on Bank Account,				0	3	4
,, Taxes recovered from Landlord,				2	14	9
				£342	2	10¼

Cr.

1868.—*Oct.* 31.			
By New Books and Binding,	£94	17	9
,, Printing *Proceedings*, Circulars, &c.,	42	11	0
,, Stationery and Advertising,	2	17	11
,, Salaries and Wages,	110	0	0
,, Delivering and Posting Circulars,	19	4	6
,, Rent, Insurance, Gas, Coal, and Water,	57	9	5
,, Taxes and Petty Charges,	14	3	10
,, Balance—In Union Bank of Scotland,	0	3	4
,, Treasurer's hands,	0	15	1½
	£342	2	10½

The Secretary read the Annual Report by the Council on the State of the Society, as follows:—

Report by the Council on the State of the Society.

I. *The New Rooms.*—The most notable incident in the progress of the Society during the past year is the completion of the arrangement with the Town Council for its accommodation in the Corporation Buildings, Sauchiehall Street. The details of the prolonged negotiation which has resulted in this desirable settlement have been so recently brought before the Society in the President's opening address, that it is unnecessary to repeat them on the present occasion. The Council have been disappointed in the expectation they were led to entertain of the new apartments being ready for the meetings of the Society and the reception of the Library at the commencement of the Session. The Town Council's Committee on the Corporation Buildings have, however, done what they could to obviate the inconvenience caused by this delay, by consenting to the Society's meetings being held in the Gallery of Art. As the Hall in Anderson's University continues in the Society's possession till next Whitsunday, the Council deem it advisable not to remove the Library from that place so long as there is any risk of its suffering from damp or dust in the new room, while the alterations are in progress in the adjoining apartments. The Council have pleasure in recording their high sense of obligation to the retiring President, Dr. Francis H. Thomson, for his active exertions in maturing the arrangement with the Town Council; and they hope that the Society will still enjoy the benefit of his services, as a member of Council, in carrying out the plans which already owe so much to his zeal and industry.

II. *The Chemical Section.*—The institution of a Chemical Section

is another event of the past year on which the Society has to congratulate itself. The Section embraces a considerable proportion of the Society's members, together with numerous Associates. To the last part of the Society's printed *Proceedings* it furnished several papers of great practical importance. It has also shown a praiseworthy desire to add to the members of the Society, which is thus deriving from the Chemical Section no small share of fresh interest and numerical strength. In these circumstances, the Council have no doubt that the Society will be disposed to take a liberal view of the claims of the Section upon its encouragement and support.

III. *The Proceedings.*—The printed *Proceedings* of Session 1867-68 completed the sixth volume published by the Society, and, including the table of Contents, Index, and List of Donations to the Library for the previous year, extended to 190 pages. The manufacture of jute, as practised in the extensive works at Dundee; the rise and progress of the production of mineral oils, and their use as fuel; and the improvements in iron manufacture, more especially with regard to Bessemer's process, were amongst the topics treated of in the address by the President at the opening of the Session. Mr. St. John Vincent Day contributed an elaborate paper "On the Great Pyramid of Egypt," with supplementary remarks by Mr. William Petrie "On the Sun's Distance and the Great Pyramid." In another contribution, Mr. Day gave "An Account of the present state of some Branches of Iron Metallurgy." "A new Plastic Material," the invention of Mr. John Clark, jun., of Mile-end, Glasgow, was described by Mr. Edmund Hunt. For the following papers, the Society was indebted to the Chemical Section, viz.:—"On the Sources of Sulphur used in the Manufacture of Sulphuric Acid," by Mr. James Mactear; "On the Recovery of Sulphur from Alkali Waste," by Mr. Ludwig Mond; "On Animal Charcoal, particularly in relation to its Use in Sugar Refining," by Dr. William Wallace; "On the Estimation of Potassium," by Mr. James Chalmers and Mr. Robert R. Tatlock. The Rev. Mr. Crosskey and Mr. David Robertson recorded the observations made by them during a journey in Norway "On the Post-tertiary Beds" of that country.

The following additional communications were not printed in the *Proceedings*, viz.:—"On the Early History of the Distillation of Coal and other Bituminous Substances," by Dr. Thomas Anderson; "On Vibrating Strings in connection with Musical Harmony," by Mr. Alexander S. Herschel; "On the Planet Jupiter seen without his Satellites," by Professor Grant; "Account of Recent Researches respecting the Internal Heat of the Globe," by Dr. Bryce; "On the

Correlation of Force in its Bearing on Mind," by Dr. John Young. Sir William Thomson exhibited and explained new Electrical Instruments for delicate testing purposes, for use at sea. Dr. Francis H. Thomson read a paper "On the Fusibility of Trappean Rocks." Dr. Allen Thomson made a communication "On the Brain of the Marmoset and other Simiæ." Mr. James Thomson read a paper "On the Difference of Structure in some Genera of Carboniferous Corals."

IV. *Number of Members.*—It appears from the Treasurer's report that the number of members at the beginning of last Session was 278, and that this number was increased, by the addition of 23 new members during the session, to 301. From this number there fall to be deducted for arrears, 3; resigned, 5; left town, 2; dead, 5—total 15,—leaving on the roll at the commencement of the present Session, 286. The Council take leave to suggest that, in the improved circumstances of the Society, an effort should be made without delay to increase the number of its members,—an object which may be readily attained by the personal influence of the present members.

The above report having been approved of, was ordered to be printed in the *Proceedings.*

Rev. Mr. Crosskey, the Librarian, reported that during the past year 254 volumes and pamphlets had been added to the Library, which now consists of 4,450 volumes.

The Society then proceeded to the election of Office-bearers, who were appointed as follows:—

President.

James Bryce, M.A., LL.D., F.G.S.

Vice-Presidents.

Professor Robert Grant, M.A., LL.D., F.R.S.
Professor Allen Thomson, M.D., F.R.S.

Librarian.

Rev. Henry W. Crosskey, F.G.S.

Treasurer.

Mr. John Mann, C.A.

Secretary.

Mr. William Keddie, F.R.S.E.

Other Members of Council.

Mr. John Ramsay, of Kildalton.	Professor John Young, M.D., F.R.S.E.
Professor W. J. Macquorn Rankine, LL.D., F.R.S.	Mr. St. John Vincent Day, C.E.
Sir William Thomson, LL.D., F.R.S.	Mr. John Downie.
Mr. William Ramsay.	Mr. William Macadam.
Mr. George Anderson, M.P.	Mr. Edward C. C. Stanford, F.C.S.
Mr. Alex. S. Herschel, B.A.	Dr. Francis H. Thomson.

Mr. Crosskey exhibited a specimen of *Eozoön Canadense* from the Laurentian rocks of Canada. This specimen is the first which has been brought to Scotland; and its position and characteristics were described. It occurs in the oldest known rocks of North America, consisting of highly metamorphosed quartzose and calcareous beds, which, in their three great divisions of upper and lower Laurentian and Huronian, attain the thickness of 50,000 feet. This remarkable fossil is the earliest known form of life, ante-dating by a vast period the oldest Scottish fossils. It is a gigantic foraminifer, and has a very great zoological as well as geological interest, since it combines within itself characteristics now found separated amongst distinct genera of existing forms.

Professor Young remarked upon the interest of the specimen and its unequivocal organic origin; and quoted the discovery by Dr. Torell of plants in Swedish rocks of a corresponding age, as an indication that foraminifera were not the only living forms at that early period.

Mr. Crosskey proposed to prepare microscopic sections to submit to the Society at a future period. He also exhibited specimens of polished encrinital limestone from Ayrshire. During the cutting of a line of railway from West Broadstone Quarry, Mr. Craig called attention to the polished limestone, of which these were specimens. The boulder clay rests in hollows of the limestone; and beneath a very compact mass of boulder clay the limestone is striated and polished by the action of ice during the glacial period. The limestone itself is almost entirely composed of fragments of encrinites, which are exposed in every conceivable form of section. In fact, the specimens are almost as smoothly polished, and the encrinites as delicately cut in section, as though they came from a marble-polishing workshop. The force exerted to produce this effect must have been gradual,

persistent, and firm. It could not have been accomplished merely by a spasmodic crush. One of the specimens shown is remarkable from having a hollow in which the work is only half done, one of the stems being but partially smoothed down—thus further indicating the character of the ice action involved.

MR. JOHN MAYER showed a specimen of *Liquor Ammoniæ*, obtained from Glasgow sewage by means of the process patented by Mr. Gavin Chapman, Manufacturing Chemist, Dalmarnock Road, and author of a letter on the sewage question addressed to the Magistrates and Town Council, in which his process is described for extracting ammonia from this source. A quantity of sewage water, after being purified by the process, and containing a living fish, was also shown. Mr. Mayer likewise exhibited a specimen of Ransome's Patent Stone, pointing out its applicability to various purposes of use and ornament. He next exhibited a specimen of Nobel's Dynamite or Giant Powder, and described the method of its application.

MR. JOHN DOWNIE produced a block of wrought iron, 12 inches in diameter, and about the same number of inches in thickness, having a hole through it $1\frac{1}{8}$ inch in diameter, in which a charge of $6\frac{1}{2}$ ounces of dynamite had been placed. The explosion of the dynamite had rent the block in a remarkable manner. In further illustration of the power of this substance, two thicknesses of boiler plate, each $\frac{3}{8}$ths of an inch thick, were produced. Through each plate a piece of tin had been blown by a charge of dynamite placed in a wooden cylinder about 2 feet from the plate, and left open to the atmosphere. A piece of iron having a charge of dynamite placed around it, was found to be sensibly reduced in diameter and slightly elongated after the explosion.

MR. W. KEDDIE exhibited specimens of *Pavonaria quadrangularis*, a rare compound zoophyte of the family *Pennatulidæ* (known as sea pens), from Loch Etive, Argyleshire. The slender calcareous rod, forming the skeleton or axis, and which is invested with animal matter when the zoophyte is alive, measured in each specimen 2 feet 10 inches. Several specimens of the polype-bearing portion of the rod were exhibited, preserved in spirit, and showing successive rows of polypes, four or six in each row, disposed in a unilateral manner on the upper part of the flexible stem. The rod is rooted in mud, at a depth of from 12 to 20 fathoms water. This zoophyte has seldom, if ever, been found in British waters, except in the sea betwixt Kerrera and Lismore Islands, and in Loch Etive betwixt Dunolly and Dunstaffnage Castles.

This closed the business of the meeting. On finally quitting the

chair, Dr. Francis H. Thomson thanked the Society for the kindness and indulgence which had been shown to him during the period he had held the office of President.

CHEMICAL SECTION.

List of Office-bearers elected at General Meeting held on 23*d November*, 1868.

President.

DR. THOMAS ANDERSON, F.R.S.E.

Vice-Presidents.

DR. WILLIAM WALLACE, F.R.S.E.
MR. ALEXANDER WHITELAW.

Treasurer.

MR. WILLIAM ROSS HUTTON.

Secretary.

MR. ROBERT R. TATLOCK, F.C.S.

Other Members of Council.

MR. EDWD. C. C. STANFORD, F.C.S.	MR. JAMES COUPER.
MR. WILLIAM MACADAM.	MR. JAMES MACTEAR.
MR. JAMES H. BALD.	MR. JOHN E. POYNTER.
MR. JOHN JEX LONG.	MR. JOHN FERGUSON, M.A.

Corporation Buildings, December 2, 1868.

DR. BRYCE, on taking the Chair, expressed his cordial thanks for the honour conferred upon him by the Society, in appointing him to an office of so much responsibility, and assured the members that no effort should be wanting on his part to perform the duties in an efficient and satisfactory manner. After adverting to the improved position of the Society, and the prospect now opened up of increasing prosperity and greater public usefulness, he went on to review, as a fitting sequel to the address of the retiring President, the

various schemes not noticed by him, which had been from time to time proposed for the removal or utilization of the City Sewage.

The following gentlemen were elected members, viz.:—

Mr. John L. K. Jamieson, 12 Centre Street; Mr. Robert Hutchison, Merchant, 7 Park Quadrant; Dr. Andrew Fergus, Elmbank Street; Mr. Alexander Christie, Brassfounder, 30 Buchan Street, Gorbals; Mr. James Provan, 17 Gordon Street; Mr. C. A. Douglas, Yarn Agent, 19 St. James's Terrace; Mr. Campbell T. Bowie, Painter, Bothwell Street.

It having been arranged by the Council that the evening should be devoted to the consideration of the Sewage Question, the discussion was opened by the President, who was followed by Mr. Gale, Engineer to the Water Commissioners; Mr. Hugh M'Clure, Civil Engineer; Mr. Begg, Kirkintilloch; Mr. John Robertson, Dr. Gairdner, and Mr. St. John Vincent Day. The discussion was adjourned till the next meeting of the Society.

Corporation Buildings, December 16, 1868.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members of the Society, viz.:—

Mr. James Clinkskill, 124 Douglas Street; Bailie William Millar, 1 Gallowgate; Mr. Alexander M'Lean, Banker, 119 Sauchiehall Street; Dr. James Morton, 199 Bath Street; Mr. James Campbell Kemp, 2 Wilton Crescent; Mr. William Young, Chemist, 10 Clayton Terrace; Mr. Andrew L. Knox, 187 St. Vincent Street; Mr. Adam Teacher, 9 Fitzroy Place.

The discussion of the Sewage Question was resumed by Mr. Daniel Munro, who was followed by Mr. W. R. W. Smith, Mr. William Robertson, Mr. James Robertson, Dr. Dewar of Kirkcaldy, Dr. Adams, and Mr. Edward C. C. Stanford. On the motion of Dr. Wallace, the discussion was adjourned till the next meeting, on the 13th of January.

Corporation Buildings, January 13, 1869.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz.:—

Mr. J. Struthers Hamilton, Adelphi Cotton Works; Mr. William Stewart, Writer, 99 St. Vincent Street; Mr. James Smith, Manu-

facturer, Dixon Street; Mr. Donald Fisher, Writer, 194 West George Street; Dr. Mathew Charteris, Rochester Place; Mr. David George Hoey, Accountant, 119 St. Vincent Street; Mr. William Robertson, C.E., 123 St. Vincent Street; Mr. James Paterson, Merchant, 5 Madeira Court; Mr. Andrew J. Kirkpatrick, 296 Bath Crescent; Mr. John Virtue, 57 St. Vincent Crescent; Mr. Thomas L. Stillie, Merchant, 26 Renfield Street; Mr. Walter Arrol, Merchant, 18 Blythswood Square; Mr. William A. Arrol, Merchant, 18 Blythswood Square; Mr. Louis Leisler, West George Street; Mr. Frederick H. Schwabe, Athole Place.

The adjourned discussion on the Sewage Question, after the reading of a letter on the subject from Mr. James Bain, was resumed by Dr. Wallace, who was followed by Dr. Fergus, Mr. Cross, Dr. Morton, Mr. Edward Hull, of the Geological Survey, and Mr. Mayer.

Dr. Francis H. Thomson stated that a deputation from the Sewage Association had that evening submitted to the Council a proposal to join the Society as a Section of Sanitary and Social Economy; and as there was no doubt that the union would speedily take place, he moved that the subject under discussion be now remitted to that Section, with instructions to report to the Society.

The motion was agreed to.

Corporation Buildings, January 27, 1869.—*The* President *in the Chair.*

The following gentlemen were elected members, viz.:—

Mr. David Thomson, Architect, 29 St. Vincent Place; Mr. Alexander Morton, Albert Works, Hyde Park Street; Mr. Alexander C. Kirk, Engineer, 62 St. Vincent Crescent; Mr. James Deas, C.E., Resident Engineer, Clyde Trust, 4 Royal Circus; Mr. Thomas B. Auchterlonie, Chemical Manufacturer, Bellfield, Kirkintilloch; Mr. Jonathan Thomson, 136 West George Street; Dr. Robert Bell, 20 Woodlands Road; Mr. Archibald Walker, Distiller, 4 Muirhead Street; Mr. John Stevenson, Manufacturing Chemist, 23 West Nile Street; Mr. J. L. Lang, Writer, 5 Provanside; Mr. Alexander Anderson, 104 Hill Street, Garnethill.

A minute of the Council of 13th January was read, stating that a deputation from the Sewage Association had applied, on the part of that body, to be united to the Philosophical Society as a Section; and

that the Council had proposed to receive the Association as a department of the Statistical Section, to be distinguished as the Section of Sanitary and Social Economy, and to be placed on the same footing with regard to its privileges as the Chemical Section. At the meeting of Council this evening a letter was received from Mr. David G. Hoey, Secretary to the Association, intimating that at a general meeting of the Association, held on the 21st of January, it was unanimously resolved to unite with the Philosophical Society on the terms proposed.

The President now declared the Section of Sanitary and Social Economy to be duly constituted.

The President, with the concurrence of the Council, gave notice of a motion to be proposed at next meeting, on the subject of establishing a School of Mining in Glasgow.

Professor Sir William Thomson showed some of Koenig's experiments illustrating vibrations of sound by means of flames, together with an instrument contrived by Helmholtz for indicating the number of vibrations.

Corporation Buildings, February 10, 1869.—*The* President *in the Chair.*

The following gentlemen were elected members, viz.:—

Mr. Edward R. Alston, 205 Bath Street; Mr. Robert Hannay, Younger of Rusko, Ironmaster, Blochairn (Office, West Regent Street); Mr. Angus Kennedy, C.E. and I.A., 99 Bath Street; Mr. James M. Forrester, Accountant, 116 St. Vincent Street; Mr. David Storer, Colour Works, Sidney Street; Mr. Colin Campbell, Iron Merchant, 2 Granby Terrace, Hillhead; Mr. John M'Gavin, Grain Miller, 19 Elmbank Place; Mr. David Watson, Coalmaster, Bathville, near Bathgate; Mr. Hugh Steven, Ironfounder, 42 Windsor Terrace, St. George's Road; Mr. James Johnstone, Manufacturing Chemist, Coatbridge Street, Port-Dundas; Mr. John Yule, Engineer, 23 Carlton Place; Mr. James B. Mirrlees, Engineer, 336 Sauchiehall Street.

Mr. Crosskey, the Librarian, intimated that in order to facilitate the removal of the Library to the new hall, no books would be issued after the 1st of March, but that members desirous of obtaining works for consultation would be allowed to retain them till the reopening of the Library.

The following motion was proposed by the President, seconded by Mr. Day, supported by Mr. Crosskey, and unanimously adopted, viz.:—

"A proposal having lately been brought before the public for the establishment of a Lectureship on Practical Mining in this city, the Philosophical Society of Glasgow hereby desires to express its warm approval of the same. The Society is of opinion that Glasgow is in every respect the most suitable place in Scotland for the institution of such a Lectureship, for the following reasons:—1. No such Lectureship exists in Scotland. 2. Glasgow is the centre of mining and metallurgic operations which give employment to a vast population requiring instruction in everything relating to mines and mining. 3. An Engineering School is already connected with our University, needing only the addition of other lectureships to form a complete Mining School."

Mr. Robert R. Tatlock, Secretary to the Chemical Section, reported on its proceedings since the beginning of the Session, and mentioned that the Section now embraces fifty-four Associate Members not otherwise connected with the Society. The papers read, and of which an outline was now given, were on the following subjects, viz.:—

1. Chemistry of Sugar Manufacture and Refining.
2. Igniting Points of the Vapours of Commercial Oils.
3. The Potash Salt Deposits of Stassfurt.
4. The Preservation of Wood.

Corporation Buildings, February 24, 1869.—*The* President *in the Chair.*

The following gentlemen were elected members, viz.:—

Mr. Peter Beattie, Inspector of Poor of Barony Parish, Florence Villa, Crosshill; Mr. Anthony Sykes Coubrough, Blanefield, Strathblane (77 Queen Street); Mr. James Copeland, Engineer, Pulteney Street, Dobbie's Loan; Mr. H. C. Dixon, Auctioneer, Pollokshields; Mr. Arthur Herriot, Inspector of Weights and Measures, 11 Ropework Lane; Mr. William Miller, Merchant, 157 West George Street; Mr. John Mackay, Jun., Cabinet Manufacturer, 270 Sauchiehall Street.

Dr. Allen Thomson read a paper "On the Minute Structure, Development, and Comparative Anatomy of the Retina."

Corporation Buildings, March 10, 1869.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz.:—

Dr. Anderson Kirkwood, 12 Windsor Terrace, West; Mr. George M'Lellan Blair, 15 Granville Street; Mr. James M'Lellan Blair, Engineer, 16 Abbotsford Place; Mr. Albert Black, Merchant, 5 Royal Crescent; Mr. John Black, Merchant, 5 Royal Crescent; Mr. William Cross, Manufacturer, 95 Argyle Street; Mr. William Maclean, Jun., Stockbroker, 98 West George Street; Mr. Thomas A. Mathieson, Edge-tool maker, 13 East Campbell Street; Mr. James Hutton, C.A., 163 West George Street; Mr. Thomas M. Barr, C.E., 21 Rose Street, Garnethill; Mr. John Stewart, Merchant, 8 Montague Place, Bath Street; Mr. Thomas Watson, 70 Gordon Street.

MR. EDWARD HULL, F.R.S., District Surveyor of the Geological Survey of Scotland, read a paper "On the Extension of the Coal Fields of England beneath the more recent Geological Formations."

On the motion of the President, the thanks of the Society were voted to Mr. Hull for his communication.

Corporation Buildings, March 24, 1869.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz.:—

Dr. Muirhead, Cambuslang; Mr. Daniel Gardner, Overnewton House, Partick; Mr. Walter M'Farlane, Chemist and Manager, Printworks, Thornliebank; Mr. George Richardson, Chemist, Messrs. C. Tennant and Co.'s, 49 Cochran Street; Mr. Robert Westlands, Hat Manufacturer, 8 Howard Street.

PROFESSOR GRANT read a paper "On the Physical Constitution of the Sun," embracing an account of the more recent discoveries.

MR. HERSCHEL offered some remarks on the connection of spectrum analysis with solar physics, and performed a number of illustrative experiments.

SIR WILLIAM THOMSON followed up Dr. Grant's paper with observations on the age of the sun and the maintenance of solar heat.

Corporation Buildings, April 14, 1869.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members, viz.:—

James M'Cann, D.D., LL.D., F.R.S.L., F.G.S., Clerk in Holy Orders, 9 Elgin Terrace, Partick; Mr. C. H. Pennycook, Gas Engineer, 100 Montrose Street; Mr. James Latta, Merchant, 1 North Claremont Street; Mr. Daniel Munro, W.S.A., 65 Bath Street; Mr. John Walker, Dalmarnock Dye Works; Mr. Graham Hardie Thomson, Iron Merchant, 24 Westminster Terrace; Mr. William Gillies, Wine Merchant, Norwell Villa, Langside; Mr. Allan Arthur, Dyer and Calico Printer, Partick; Mr. Alexander Moore, Accountant, 28 St. Vincent Place.

MR. ST. JOHN VINCENT DAY read a paper "On the Sun's Distance and Parallax."

Corporation Buildings, April 28, 1869.—*The* PRESIDENT *in the Chair.*

The REV. HENRY W. CROSSKEY read a paper "On Recent Researches into the Post-tertiary Geology of Scotland."

MR. JAMES THOMSON read "Notes on the Structure, Stratigraphical Position, and Preservation of certain Carboniferous Fossils," which were exhibited.

MR. ROBERT R. TATLOCK gave in the following report from the

CHEMICAL SECTION.

Since the last report was read to the Society, there have been six meetings, at which seven papers have been read, as follows:—

Feb. 15.—"On a New Method for the Utilization of Sewage." By Gavin Chapman, Esq.

March 1.—"On the Origin and recent Progress of Spectrum Analysis." By Alex. S. Herschel, Esq., B.A., F.R.A.S.

March 15.—"Observations on some Artificial Colouring Matters." By W. H. Perkin, Esq., F.R.S.

March 29.—"On the Examination of the Flame of the Bessemer Converter;" and "On the Molecular Effect of Phosphorus on Iron." By Thomas Rowan, Esq., F.C.S.

March 29.—"On the Duality of Compound Molecules." By J. Cameron, Esq.

April 19.—"On a New Method of Chemically Treating the Excreta of large Towns." By E. C. C. Stanford, Esq., F.C.S.

The Section has communicated with the Chemical Society of Paris, and with the Pharmaceutical Society of London, requesting these Societies to send their respective journals regularly in exchange for the *Proceedings of the Philosophical Society;* and to which they have cordially agreed.

Mr. Sigismund Schuman gave in the following report from the

SANITARY AND SOCIAL ECONOMY SECTION.

February 8, 1869.—This Section met in the Hall, Andersonian University, on Monday evening, to consider rules for its constitution. The following were finally adopted, viz. :—

CONSTITUTION.

This Section has been established for the purpose of affording opportunities for the discussion of the numerous and important subjects which are comprehended in the title of the Section, and, when deemed necessary, of taking action in reference thereto. Such subjects to be introduced at periodical meetings, by the reading of papers or by verbal communications.

The Section consists of members of the Philosophical Society, who are admitted free to its meetings, and of Associates who are not members of the Philosophical Society, who are admitted to the Section on payment of an annual subscription of Five Shillings.

Associates have the privilege of consulting the Library of the Philosophical Society.

RULES:

I. The management of the Section shall devolve upon a Committee of thirteen, consisting of a President, two Vice-Presidents, a Secretary, and nine ordinary members. Three a quorum. The term of office shall be three years; but three of the ordinary members shall retire annually. The Committee shall fill up vacancies that may occur in its number.

II. In the absence of the President, the chair shall be taken by

one of the Vice-Presidents; or, failing them, by one of the Committee.

Upon all questions of order the decision of the Chairman shall be final.

III. No paper shall be read, nor any subject introduced at the meetings, which has not been approved of by the Committee.

IV. Copies of the papers read at the meetings shall be given into the charge of the Secretary, to be kept for reference; but the author shall have the right of publication, subject to the approval of the Committee.

V. Every candidate for admission into the Section shall be proposed and seconded at an ordinary meeting, and at the following meeting shall be balloted for. A majority of votes to decide.

VI. The Associates' Annual Subscription of Five Shillings becomes due on the 1st day of November in each year.

VII. Persons not belonging to the Glasgow Philosophical Society, but whose co-operation would be valuable to the Section, shall be eligible as Honorary Members.

VIII. Any Associate desiring to withdraw from the Section shall signify the same in writing to the Secretary. Any Associate whose subscription is in arrears for two entire years may be removed by the Committee from the list of members.

IX. A meeting of the Section shall be summoned annually, in the month of November, to receive the report of the Committee, and to elect three Members of Committee for the ensuing year. The election shall be by ballot. The retiring Members of Committee shall not be eligible for re-election till after the lapse of one year.

X. The foregoing rules shall not be altered or increased without the sanction of a Special General Meeting of the Section. Notice of the proposed alteration to be given at the preceding General Meeting.

February 22, 1869.—The following gentlemen have been elected the Office-bearers for this Session:—

President.

CHARLES RANDOLPH, ESQ.

Vice-Presidents.

ANDREW FERGUS, ESQ., M.D.
W. R. W. SMITH, ESQ.

Secretary.

D. G. Hoey, Esq.

Ordinary Members of Committee.

Messrs. Thomas Hoey.
„ James Anderson, 98 St. Vincent Street.
„ James Deas, C.E.
„ Robert Leggatt.

Messrs. William M'Adam.
„ Councillor Matheson.
„ Bailie Mirrlees.
„ Sigismund Schuman.
„ Councillor Ure.

Mr. T. Hoey read a paper upon "Supply of Gas," which was followed by a lively discussion.

March 8, 1869.—In accordance with the desire expressed by the Philosophical Society, at the meeting of January 13, 1869, that this Section should continue investigations as to the best means for the removal and disposal of human excreta and other obnoxious matter now flowing through the city in sewers, and to their probable utilization, a paper, prepared by Mr. Gavin Chapman, was read, proposing that a system of pipes should connect the water-closets with tanks at a suitable distance, the product treated with lime, precipitated and heated to give off the ammonia, which is to be fixed as a commercial product. Mr. Chapman computed that if his treatment be carried out, the excreta, instead of, as at present, being diluted with foreign matter in the sewers and becoming a nuisance, will not only pay for the expense of recovery, but also leave annually a large amount of profit.

Mr. E. C. C. Stanford criticized Mr. Chapman's mode of procedure from a chemical point, having great doubts whether Mr. Chapman's object could possibly be attained with the comparative small quantity of fuel he calculated in his estimates. Several gentlemen took part in the discussion.

March 22, 1869.—Mr. W. R. W. Smith, one of the Vice-Presidents of the Section, opened the discussion, following up the subject of the previous meeting; also reading extracts from a book of pamphlets by

Mr. Glassford, formerly of this city, who is of opinion that human excreta, collected and chemically treated, can be fixed into an inoffensive portable product of commercial value.

April 12, 1869.—Mr. Thomas Hoey exhibited a model, also drawings of arrangements, for the collection and disposal of human excreta. He proposed the quantity of water used for flushing the water-closets be limited, say to the seventh part of a gallon for each usage of the closet; this water to be mixed with a small quantity of sulphuric acid, which will fix the ammonia and other valuable products of the excreta, and prevent decomposition and development of noxious gases. The model exhibited by Mr. Hoey showed an ingenious arrangement to effect his object. All the matter thus obtained is to accumulate at a convenient place until carted away to a depôt, and there treated, according to his plan, mechanically and chemically, for manure. The product thus obtained will be portable, inoffensive to health when stored up, and of a commercial value; and when sold, will pay expenses, interest on the capital, and realize large profits.

Mr. John Begg, of Kirkintilloch, read a paper. He compared the method of Sewage Irrigation, which requires not only a large outlay of capital, sunk in pipes, machinery, and land, but also heavy daily expenses for pumping the large volume of fluids to distant places (taking Messrs. Bateman and Bazalgette's estimates, as prepared for this city, as a standard), and pointing out the more than doubtful result of its value to agricultural purposes, from the immense dilution of the valuable ingredients of the excreta with the volume of foreign matter and water, with Captain Lieurnur's system, which is simply to keep all water and foreign matter away from the excreta when deposited, and allow it to glide into a well which is connected with pipes laid to a suitable place, where a pneumatic engine attached to carts, with hermetically closed tanks, is to operate for its daily removal, and at suitable depôts to be filled into barrels, and sold to farmers. He further suggested that, in order not to interfere with the present water-closet arrangements, he might limit the quantity of water for each flushing by a meter, or other simple apparatus; allow the quantity to flow through pipes with valves at the end of them; a number of these pipes collected at a certain spot to open into one central or sectional pipe; and these various pipes to terminate at one particular place. Engines are to work by pneumatic pressure to drive

together, at certain periods, all the matter, and thence, through one large pipe, the whole accumulations to be driven by pneumatic pressure to distant fields. Mr. Chapman's arrangements he criticized as unworkable, owing to the size and quantity of tanks he would require to manipulate with, in order to dispose of the large volume of matter flowing through them; and he further objected to this mode of treatment on account of the nuisance it would cause when decomposition is going on. After criticizing Mr. Hoey's arrangement as unpractical, the further discussion of the subject was adjourned till the next meeting.

April 26, 1869.—At the closing meeting of this session the adjourned discussion was opened by Mr. Chapman. He believed that the cast-iron pipes which Captain Lieurnur's plan requires would soon be corroded and leave holes, rendering them useless for working with air-pressure. To travel through the streets with high-pressure engines for pneumatic purposes would be a great nuisance to the traffic. The expense, as estimated in Mr. Krepp's book, for this plan for plant, machinery, &c., is far above the estimates for his arrangements; while the product, when collected, would still remain bulky and offensive to work with, if not even detrimental to the health of those who have to work it, unless it were put in the ground immediately after being collected. He considered Captain Lieurnur's machinery for the distribution of the product on the fields as unpractical.

Mr. Begg then explained again the second part of his plan, whereby he drives the product by pneumatic pressure into the fields, on which he proposed to grow mangel-wurzels for sugar-making, estimating the production at 50 tons per acre.

Mr. Hoey contended that it is impossible to work Mr. Begg's system of pipes in the manner described; the whole plan, therefore, is useless.

Councillor Ure read a letter addressed to him by Mr. W. H. Hughan, Newton-Stewart, describing his patent to turn sewage into manure by mixing it with Roman cement and copperas, and churning it, which he considered would fix all the valuable ingredients and precipitate them. After running off the water, the precipitate will remain as a valuable manure. He estimated that a profit would accrue to this city, were his patent adopted, to solve the difficulty of the Sewage Question. He further stated that the water thus run off is quite pure and pleasant to drink, and that he and a medical

friend of his drank the water thus purified from Glasgow sewage. The quantity of sewage water he estimated at 1,000,000 gallons daily.

Dr. Fergus drew attention to the fact, in connection with sewage water, that it might be inoffensive to the smell, and yet full of animal matter; it might even be pleasant and cooling, owing to the presence of nitrates, and nevertheless be dangerous to drink—citing a case in point.

The proceedings closed with a vote of thanks to Dr. Andrew Fergus for his judicious and able conduct in the chair; which was proposed by Councillor Ure, and heartily responded to by all present.

Extract from the Minutes.

The Committee of this Section met in the Secretary's office on Friday, the 23d April, at one o'clock; and Mr. Sig. Schuman was requested to draw up the report of the proceedings of this Section for this Session, to be read at the meeting of the Philosophical Society, and to be placed in the hands of the Society, according to the Society's rules.

The President congratulated the Society on the close of a very successful Session, in which a great addition had been made to the roll of members. A succession of important and interesting papers had been brought forward at their meetings, and another Section—that of Sanitary and Social Economy—had been instituted. After pointing out the advantages to be derived from a union of the Scientific Societies of Glasgow, he mentioned that there was reason to expect that at an early period several other Societies would follow the example of the two which had already joined the Philosophical Society. The President then announced the close of the Session.

DONATIONS TO THE LIBRARY,

FROM 1ST MAY, 1868, TO 30TH APRIL, 1869.

Title.	Donor.
Report upon the Vital, Social, and Economic Statistics of Glasgow, for 1867, by Wm. West Watson, F.S.S.,	*The Author.*
Proceedings of the Liverpool Geological Society, for 1867-68,	*The Society.*
Proceedings of the Bath Natural History and Antiquarian Field Club. No. 2. 1868,	*The Club.*
Authorship of the Practical Electric Telegraph of Great Britain, by Rev. Thomas Fothergill Cooke, M.A.,	*The Author.*
Transactions of the Cambridge Philosophical Society. Vols. VII.-IX.; X., Parts 1 and 2; XI., Part 1. 1839-66,	*The Society.*
Essai sur la Métaphysique des Forces, par Alexandre Schyanoff. 1868,	*The Author.*
Review and Journal of the Anthropological Society of London. Nos. 22-25. 1868-69,	*The Society.*
Journal of the Scottish Meteorological Society. New Series. Nos. 18-21. 1868-69,	*The Society.*
Proceedings of the Cotteswold Naturalists' Field Club, for 1867,	*The Club.*
Memoirs of the Geological Survey of India. Vol. VI., Parts 1 and 2,	*The Governor-General of India.*
Palæontologia Indica. Series 5. Nos. 1-4,	*Ibid.*
Annual Report, 1867,	*Ibid.*
Catalogue of Meteorites, &c.,	*Ibid.*
Journal of the Royal Institution of Cornwall. No. 9. April, 1868,	*The Institution.*
Mémoires de la Société des Sciences Physiques et Naturelles de Bordeaux. Tome V., Cahier 3. Et Proces-Verbaux, 1867. Tome VI., Cahier 2. 1868,	*The Society.*
Transactions of the Woolhope Club, for 1867,	*The Club.*
Proceedings of the Institution of Mechanical Engineers,	*The Institution.*
On Waves which travel along with Ships, by W. J. Macquorn Rankine, C.E., LL.D., F.R.S.,	*The Author.*
Monatsbericht der König. Preuss. Akademie der Wissenschaften zu Berlin, Mai, 1868,	*The Academy.*

Title.	Donor.
Proceedings of the Royal Institution of Great Britain. Vol. V., Parts 3 and 4. 1868, ...	*The Institution.*
Report of the Leeds Philosophical and Literary Society, for 1867-68, ...	*The Society.*
Smithsonian Miscellaneous Collections. Vol. I. 1862, .	*The Institution.*
———— Contributions to Knowledge. Vols. VII.-X. 1855-58, ...	*Ibid.*
Annual Report of the Smithsonian Institution for 1866,	*Ibid.*
Proceedings of the Boston Society of Natural History. Vols. III.-IX., and XI., ...	*The Society.*
Memoirs ————. Vol. I. Part 3,	*Ibid.*
Annual ————. No. 1. 1868-69,	*Ibid.*
Condition and Doings ————. May, 1867, and May, 1868, ...	*Ibid.*
Transactions of the Academy of Science of St. Louis. Vols. I and II. 1856-68, ...	*The Academy.*
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PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SIXTY-EIGHTH SESSION.

I.—*Opening Address by* James Bryce, M.A., LL.D., F.G.S., *the* President.

November 3, 1869.

The President's address was chiefly devoted to an account of the life and labours of the late Mr. Thomas Graham, Master of the Mint, with notices of deceased members of the Society. The following is an outline:—

After making some preliminary observations in regard to the progress of the Society during the last session, and the programme of the Council for that now opening, the President went on to give an account of the leading events in the lives of several members, whose loss by death during the past year the Society had to deplore.

I place first on this sad roll the name of one of the most noble-hearted and most gifted of Scotland's many gifted sons—a name of which this city, and all the Institutions with which it is associated—indeed, this whole nation—has good reason to feel proud—the name of Thomas Graham, late Master of the Mint, whose mortal remains were accompanied to their last resting-place, in the grounds of our High Church, about five weeks since, by many gentlemen whom I now see around me. Mr. Graham had for several years been in the habit of going down from London to Malvern from time to time, for bracing air and change of scene. A visit with this object was made early in September last, and was so much profited by, that he determined to take the journey to Glasgow, where it was usual for him to spend a portion of every autumn among his relatives, and then to reside on his estate in Stirlingshire. Returning from a

long walk, heated and fatigued, he threw himself on a couch, and fell asleep, having unfortunately omitted to shut down an open window. A severe chill was the result, ending in inflammation of the lungs. Next morning he hurried back to London, had the best advice and care at once, and the disease was completely got under. But being of slight frame, and spare habit, he had little strength to draw upon, and sank from the weakness following the sharp treatment. He died in his sixty-fourth year.

Thomas Graham was born in Glasgow, on 21st December, 1805. His father was a manufacturer of light fabrics, adapted to the climate of the West Indies, to which he exported them direct. He had been successful in this enterprise, and was then carrying on a prosperous business, though as yet he could not be called a rich man. He had four other sons, and two daughters—one of whom is the wife of our respected townsman, and former Treasurer of this Society, Mr. James Reid, banker, and the only surviving member of the family.

Thomas Graham received his early education at the preparatory school of Dr. Angus, who long enjoyed a high reputation in the West of Scotland as a teacher of English. In 1814 he entered the Grammar School, since called the High School, and received his classical education under Dr. Dymock and Dr. Chrystal. In his course of five years he often gained distinction in the classes, being noted for cleverness, industry, and proficiency. In 1819 he passed on in due course to the University, and went through the complete curriculum, at the close of which he proceeded to the degree of A.M. This was probably taken in view of his father having destined him for the church. Two of his uncles had good livings in the established church, and the family had such interest as would have insured a presentation for young Graham; but he steadfastly resisted argument and importunity, determined, he declared, to give himself to chemistry. He had conceived a passion for this delightful science, for the origin of which, as in the case of Faraday, it is very difficult to account. At home he carried on many experiments, and, like all young chemists, often with the most simple improvised apparatus. Some pieces of this have been preserved by his relatives, and introduced with good effect into a late photograph of the philosopher. It was fortunate that he chose this walk. He had no gifts for the ministry; and had he adopted it, he would not have been happy—he would have missed that repose, peace, and enjoyment, which his whole life manifests, and that immortal name by which he is for ever associated with the course of scientific discovery. Mr. Graham's chemical education

was carried on at Glasgow University, under the late Dr. Thomas Thomson, from whom he received that attention and kind encouragement bestowed upon all students who took an interest in the work of his class, and of which I myself cherish a most grateful recollection. He went afterwards to Edinburgh and studied under Dr. Hope, returning again to Glasgow in 1827.

To those who know something regarding the great objects of chemical research, it will be obvious how necessary is not only the mental culture and discipline which mathematics of all studies is best fitted to give, but also a high amount of attainment in mathematical analysis. Dalton was an able mathematician, and, like him, Mr. Graham was well versed in this science. Like Dalton, too, he was for some time a teacher of mathematics. Wishing apparently to do something towards maintaining himself, as he had adopted his profession in opposition to his father's wishes, he opened private classes for teaching mathematics, under the patronage of Dr. Meikleham, the Professor of Natural Philosophy. But his devotion to his favourite study soon led him to abandon this pursuit, and to open a private laboratory in North Portland Street for instruction in chemistry and performing of analyses. In 1829 he was appointed Lecturer on Chemistry to the Mechanics' Institution, and in 1830 became successor to Dr. Ure as Professor in Anderson's University. Here he continued for seven years, teaching chemistry with eminent success, and conducting the laboratory, which has always been an important object in that excellent institution. Occasionally he delivered lectures on chemistry to ladies, which were well attended —not the only instance in which Glasgow has anticipated the great movement of the present time. It was during this period that Mr. Graham took an active part in the proceedings of our Society, and was for several years Vice-President—Dr. Thomson being President for life. To the same period belong many of his papers, to which I shall again refer in my estimate of his labours. Two were of special importance, placed him in the first rank of European chemists, and led to the bestowal upon him of two medals, the "Keith Medal" of the Royal Society of Edinburgh in 1834, and the "Royal Medal" of the Royal Society of London in 1838, for researches made two years before. In 1837 he was appointed to the Chair of Chemistry in University College, London. This he held for eighteen years, prosecuting his important chemical researches with untiring industry and distinguished success. For several years at this period he had constantly at his right hand an honoured friend, in whom his chief confidence was placed. James Young, now of Kelly, his assistant

in Glasgow, removed with him to London, and under this great master of new methods and original research attained that power of grasping principles which enabled him, while amassing a colossal fortune, to open up the prospect to us of utilizing for centuries to come the refuse heaps of our coal pits and iron mines, when the existence of our coal and ironstone shall be but traditions of the past.

Placed now at the centre of scientific activity where his merits were thoroughly appreciated, Graham found honours and emoluments flowing in upon him, unsought. He was elected a corresponding member of the French Academy, and a member of all the most important foreign Societies. The office of Joint Assayer to the Mint was conferred upon him, which added considerably to his fixed income, and he was frequently employed by the Bank of England to make assays. As an analytical chemist, he could have realized a very large income. Mr. Faraday, Dr. Tyndal assures us, could have made £5,000 a year in this way, but chose to remain a poor man that he might have leisure to pursue original research. Mr. Graham also, in most cases, declined. On one occasion a great brewing house applied to him to analyze their beer, in regard to which a panic pervaded the public mind, that it contained strychnine. Mr. Graham declined on the ground of time, that he did not wish for such work, and, to keep it from coming to him, had made up his mind to charge for an analysis a fee of £100. Next morning he received a cheque for £200, with an earnest appeal to do an act of justice and allay the panic. This appeal he could not resist. He called in Dr. Hofmann, of the College of Chemistry, gave him half the fee, and the analysis was soon made widely known. Yet it was several years before the sales reached the old figure. Independently altogether of the analysis, it was shewn how senseless and absurd was the panic. Every part of the process is carried on in the most open manner, rendering fraud and concealment impossible. The quantity made yearly would require 16,448 oz. of strychnine to give the bitter flavour, the cost of which would be £13,158; while at the time not more than 1,000 oz. were made all the world over. Besides, the flavour given by strychnine is peculiar, and quite unlike that of the beer in question (*Journal of Chemical Society*, vol. v., 1853).

In 1841 he united with a few other chemists in forming the Chemical Society of London, now a great and prosperous body. He was chosen its first President. In 1842 he published a treatise on Inorganic Chemistry—an admirable outline of that part of the science —which has held its place well, and passed through several editions.

During Mr. Graham's occupancy of the chair of chemistry his father

died suddenly without a will, and he became heir to an estate in Stirlingshire and a very considerable amount of other property. This latter he divided among a few near relatives, and retained only the landed property—an honourable example of disinterestedness, in keeping with the noble generosity and unselfishness of his whole life. As Mr. Graham was never married, this property is inherited by the son of one of his brothers. In 1855, on the retirement of Sir John Herschel, Mr. Graham was appointed Master of the Mint. Thus for the second time this important office, to which a salary of £1,500 per annum is attached, was bestowed for eminent scientific attainments, and not for political services. It is greatly to be desired that this principle should always rule the appointment; and not only that such an office should be maintained, and reserved as a reward for labours which do not pay of themselves, but that many such existed among us, as they do in other countries more democratic than our own. Such public recognition of services of this kind would be the best investment the nation could make of a few thousands yearly.

The duties of the Master being comparatively light, and mostly dischargeable by deputy, Mr. Graham had now more leisure, and freedom from distraction, than he had ever before enjoyed, and he was not slow to profit by it. He pursued his inquiries with unremitting ardour for fourteen years, and had the good fortune, three months before his death, to elaborate the series of experiments which finally established one of the most brilliant discoveries in the records of science.

There is great interest, in a psychological point of view, in trying to discover the circumstances which have determined great men towards a particular line of study or scientific research. But there is great difficulty also in the inquiry. The men are not great at first —and no one probably thinks of observing. The men themselves either do not know, or, from various motives, leave no record, and the early circumstances are forgotten. Faraday says, regarding himself, as Dr. Tyndal tells us, that he found the beginning of his philosophy in the books he was binding during the day, by reading them in the hours after work. Two especially helped him—the *Encyclopædia Britannica*, from which he gained his first notions of electricity, and Mrs. Marcet's *Conversations on Chemistry*, which gave him his foundation in that science. "I was not a deep thinker nor precocious. I was very lively and imaginative, and could believe in the *Arabian Nights* as easily as in the *Encyclopædia;* but facts were important to me, and saved me." (*Faraday as a Discoverer*, by Dr. Tyndal, page 3.)

This is interesting and important; but it does not go far enough back. One would like to know from Faraday why he read these books after his day's work was done, and how they did for him what they did not do for others. He did not know probably, and perhaps few men do know. There seems, indeed, to be an inherent, constitutional difference,—that this seizes upon outward circumstances in harmony with the tone within; these again react upon the mind as appropriate food; the faculty and taste are developed; and when coupled with a high, imaginative, or inventive faculty, and a power of close accurate perception, give us a great scientific genius. If I might venture a conjecture in Graham's case, in the absence of all tradition in regard to a determining cause, I would suggest, as probable, the surroundings in his chemical education. Thomson was busy in his laboratory with a complete overhaul of Dalton's *Atomic Theory*, and determination of all the combining proportions to a new unit. This led naturally to the study of molecular philosophy, the properties, the play, the forces of atoms. Doubtless, in Graham's mind, as originally constituted, there was some determining habitude which fell in with this, and was nourished by it; and thus may have been formed that style of philosophizing which runs through most of his chemical work. For carrying on such work, indeed, his mind was singularly fitted. He was patient, calm, sagacious—yet with a lively imaginative faculty, which could see a great truth far off, looming out from complex relations and interactions, and could trace the development of Law and Order where a mind not thus constituted would have been lost in details. Mr. Graham was indeed almost an impersonation of calm philosophy and pure reason, free from passion and prejudice, the intellect and moral sense ruling supreme. He was a man of simple, retiring character, neither self-asserting nor self-magnifying. He never courted applause or cared for a popular reputation. He never sought to gather about him a group of worshippers, who should sit at his feet, and go abroad to proclaim his doctrines. He pursued apart, in the calm repose of a contented life, an unbroken series of philosophic inquiries; the results of which were sent forth, from time to time, upon the world of science, to make their own way as they might. His papers, almost from the very first, when he was between his twenty-first and twenty-fifth years, are a model of clear statement, in terse and suitable language, with now and then a flashing-out, in a few eloquent words, of the great imaginative fire within, whose warmth sustained all this energy of work, and yet, alas, consumed the frail tenement which held it!

I shall now notice briefly the leading researches and discoveries

of Mr. Graham. His first paper was written when he was twenty-one years of age. It is on the "Absorption of Gases by Liquids," and appeared both in the *Scots Mechanic's Magazine* and in the *Annals of Philosophy* for July, 1826, (vol. xxviii., or N. S., vol. xii.) He endeavours to shew that, in cases of such absorption, the gas passes into the liquid form, and that those gases are most absorbable which are most easily reduced by pressure or great cold into the liquid form. Doubtless, Faraday's great discovery of the liquefaction of gases, made three years before, had suggested the train of thought and experiment. It is not a little remarkable that this view of gases being liquefied on absorption, and not merely passing into the pores, made forty years ago by a young man of twenty-one, in his first paper, should now be completely confirmed, and have become a recognized principle in chemical philosophy.* During the four years following, Mr. Graham's papers treat of many subjects:—"The Heat of Friction," a groping in the dark after a great truth (*An. Phil.*, xii., page 260); "The Production of Alcohol in the course of the Fermentation of Bread in Baking" (same vol., page 363); "On the Influence of the Air in determining the Crystallization of Saline Solutions;" "An Account of the Formation of Alcoates, definite Compounds of Salts and Alcohol, analogous to the Hydrates," read to the Royal Soc., Edinburgh, December 17th, 1827 (*Transactions*, vol. xi., pages 114, 175); "The Action of Animal Charcoal on various Solutions"—its action on colouring matter being only known before (*Quarterly Journal of Science*, vol. vii., N. S., page 120, 1830); "On the Oxidation of Phosphorus," more or less rapid, according to the medium it is placed in (*Quarterly Journal*, vol. vi., N. S., page 83); "On the Absorption of Carbonic Acid through the Pores of a Moist Bladder, partly filled with another Gas" (same vol., page 88); a series of short articles, entitled "Chemical Observations" (same vol., page 354); "On Platinum, applied to Eudiometry;" "On Crystallization of Barley-sugar;" "On Detection of Arsenic;" "On Chrome Orange."

Of the same date as several of these, and published in the same volume with them, there is "A Short Account of Experimental Re-

* The peculiar relations in which gases and liquids stand to one another have been finally established by an admirably lucid and conclusive memoir, just published—the *Bakerian Lecture* for 1869, read to the Royal Society of London, June 17th, by Dr. Andrews, V. P. of Queen's College, Belfast. It is there shewn that the gaseous and liquid forms of matter may be transformed into one another by a series of *unbroken physical changes*—the gas and the liquid being only distant stages of a *perfectly continuous process*.

searches on the Diffusion of Gases through each other, and their Separation by Mechanical Means" (*Quarterly Journal of Science*, vol. vi., N. S., page 74); closing with the suggestion of a law, but reserving the subject for further inquiry. He was now a Fellow of the Royal Society of Edinburgh, having been elected in 1828; and to this Society, having extended his experiments and matured his views by two years' further research, he submitted his completed paper on the subject, on the 17th of December, 1831, being then in his twenty-sixth year. It is in every way a masterly production, whether we regard the logical form, the experimental skill, the mathematical development of a law, or the establishment of a great truth in physical science. Its publication placed the author at once in the first rank among European chemists. Soon after, the Royal Society of Edinburgh bestowed upon him the Keith Medal, the highest distinction in their power to confer. Mr. Graham shewed that the same volume of different gases escaped in times which are very unequal, and depend on the density or specific gravity of the gases—light gases diffuse more readily, heavy gases more slowly. If we have hydrogen on one side of a screen or diaphragm, with pores or apertures perfectly insensible, and air on the other side, an interchange takes place,—one measure of air is exchanged for $3\frac{8}{10}$th measures of hydrogen, and the interchange continues to go on rapidly till the gases are in a state of uniform mixture. These volumes, 1 and $3\frac{8}{10}$ths, are the "*Diffusion Volumes*" of these two gases; and he ascertained the numerical proportions of such volumes for all gases. They are plainly measures of the *force* of *diffusion*, and represent the molecular energy of each gas; and he demonstrated that this force is inversely as the square roots of the densities of the gases. If two equal receivers be filled, one with oxygen and the other with hydrogen, and separated by a porous membrane, or plug of stucco, diffusion begins; and for every *one* part of oxygen which passes into the hydrogen, *four* parts of hydrogen pass into the oxygen. Now, the density of hydrogen being 1, that of oxygen is 16, and the force of diffusion is 4 to 1, or four times *greater* for the gas of *less* density. This force, he shewed, resides in the ultimate particles: it is a property of these, and not of masses or volumes of the gases, and is therefore not the result of accident, but of an inherent force in the ultimate molecules of all matter in the gaseous form. This is fully established by the fact that inequality of density is not necessary to diffusion,—two gases of the same density will diffuse into one another, the rates being of course in this case equal.

The same principle is applicable to the separation of mixed gases, by bringing the mixture into connection with a confined gaseous

atmosphere. This is, in fact, only a continuation of the process; the most diffusive gas passes away in the greatest proportion; and by continuing the process, this gas can soon be had in a separate form—the atmosphere into which the diffusion is effected being of such a kind as may afterwards be condensed, or absorbed with facility (*Trans.*, R. S., E., vol. xii., page 222).

The papers of Mr. Graham, which appeared after these, in the *Transactions of the Royal Society, Edinburgh* (vol. xiii., xiv.), and other journals, "On Phosphorated Hydrogen," "Water as a Constituent of Salts" (December 1, 1834, January 5, 1835), "On the Arseniates and Phosphates," fully maintained the high reputation of their author. They gave extension and precision to chemical theory on many important subjects, though not possessing that brilliancy which marks so many of his papers.

Mr. Graham was elected a Fellow of the Royal Society in 1836 (December 15), and to its *Transactions* for that year he contributed a paper "On the Constitution of Salts, Oxalates, Nitrates, Phosphates, Sulphates, and Chlorides," which was deemed so important an addition to Chemical Science, that the Royal Medal was bestowed upon him in 1838. Having permanently removed to London in 1837, his papers are now mostly contributed to the Royal Society.

The great subject peculiarly his own was first resumed by him, and I may say completed, with the same mastery over details, the same wide and searching experiments, and the like development of law which had marked his former paper. The motions of gases were now treated under the two remaining heads of "Effusion into a Vacuum," or the passage through fine apertures in plates, and "Transpiration," or the passage into a vacuum along capillary tubes. The Effusion followed the same law as the Diffusion already stated; while the Transpiration rates have no relation to the density. The rate of oxygen is less than that of any other gas; and while the rates of some are directly as the density, others do not follow this law,—all transpire more rapidly the higher the pressure; to this, Effusion has no relation.

It was for these Researches on Gases that the Royal Medal was conferred upon Mr. Graham, in 1850, by the Council of the Royal Society.

Mr. Graham's public position in London naturally led to his frequent employment by the Government and public bodies, to draw up special reports on various subjects. These are as follows:—"On the Cause of the Fire in the Steamer 'Amazon,'" to the Privy Council, in *Jour. of Chem. Soc.*, vol. v., 1853, page 34;

[illegible]

[illegible] movements of gases [illegible] the same [illegible] in liquids, and we [illegible] the Diffusion of Liquids and [illegible] which, while they are [illegible] curious and interest- [illegible] the results of the [illegible] The subject was [illegible] new — wholly [illegible] that he [illegible] He [illegible] and to search [illegible] present to his [illegible] and that of the [illegible] — the whole phenomenon, indeed, had

been masked and complicated by being looked at in connection with Endosmose, where the imbibing power of a membrane comes into play. For the Bakerian Lecture of 1850 he chose this subject. The nature of the inquiry is best understood from a simple experiment:—Into the bottom of a glass cylinder, filled with water, introduce, by means of a pipette, a mixed solution of salts—say common salt and muriate of potash—which can quite well be done without disturbing the water. The two salts immediately begin to rise through the water, but at unequal rates, and after several days there will be a tolerably complete separation,—so that if water be drawn off at different levels, it will be found to contain very different quantities of the two salts. The one diffuses more rapidly than the other; and if time be given, the separation of the two will be complete.

In the course of his exhaustive inquiry, Mr. Graham developed many beautiful laws, which place Liquid Diffusion in the closest possible relation to Gaseous Diffusion,—a relation "reaching down to the very basis of molecular chemistry." We deal no longer with the atoms of Dalton, but with masses more simply related in weight. We may suppose that these atoms, which are the true combining proportions in all chemical combinations, are grouped together in such numbers as to form larger molecules, either of equal weights for different substances, or of weights bearing a simple relation to one another. "It is this new class of molecules, and not the Daltonian Atoms, which play so important a part in Liquid and Gaseous Diffusion."

Among the vast variety of substances examined with reference to their diffusibility, another grand relation was established. Those having high diffusive mobility are such as crystallize readily; those of low mobility either do not crystallize, or are made to take this form with extreme difficulty. This latter class comprehends starch, albumen, the gums, hydrated silicates, and many others; the highest of which has *seven times less mobility* than Epsom Salt, the least diffusible of the other class. Gelatine being the type of the bodies of this second class, Mr. Graham has given the group the name of Colloids, from the Greek *Kolle,* jelly; the others, of course, are crystalloids. They appear like different worlds of matter. Their properties are characteristically different,—of the one is built up an animal and vegetable world, of the other a mineral kingdom. The distinction between them is one of intimate molecular constitution; and there is no doubt that the peculiar aggregation, state of mobility, and chemical indifference, admirably fit the Colloid struc-

ture for the part it plays in the organic processes of life. It alone possesses *Energia*, and may be looked upon as the probable primary source of the force, appearing in all the phenomena of vitality (*Philosophical Transactions*, 1850, page 1).

An admirable application of these views, suggested at the very first, but not then followed up, was made by Mr. Graham himself, under the title, "Liquid Diffusion applied to Analysis" (*Philosophical Transactions*, 1861). He had in the interval delivered a second Bakerian Lecture "On the Osmotic Force" (*Philosophical Transactions*, 1854). This refers to the singular property possessed by certain membranes of promoting the interchange of substances placed in contact with them—discovered before Graham's time by Dutrochet, and named by him Endosmose and Exosmose, from the *directions* of this interchange. The membrane or septum must be a colloid, and its two surfaces must be exposed to chemical actions of different kinds, and more intense on the one side than on the other. Graham had carefully studied the phenomena for himself, and conducted a long experimental inquiry upon the action of this singular molecular force in a great variety of substances; and he was therefore now in a much better condition to apply the principles of diffusion to a complete separation of substances in solution. It was found that though colloids are chemically inert in the ordinary sense, yet they have a peculiar activity, arising from their constitution; their softness partakes of fluidity, and enables them to become a medium of Liquid Diffusion, like water itself. Hence comes their use in aiding the separation of the ingredients in a solution. To such separation Mr. Graham applied the term "Dialysis." The most suitable membrane to employ as a septum is parchment paper—that is, unsized paper, altered by a short immersion in sulphuric acid. In a wetted state, this paper can easily be applied to a gutta percha hoop, and fastened by a string or elastic band, so as to form the bottom of a small tray, like a sieve in shape. This tray is the "Dialyser." Into it is put the mixture to be examined, and the tray is then floated on the surface of a shallow dish of pure water. In a day or two, the solid or crystalloid in the mixture will diffuse out through the septum into the pure water, and so be easily had in a separate state—perfectly pure. A mineral poison, for example, mixed with various articles of food, *diffuses out* in this way in a short time, and is obtained quite pure. The process has this immense advantage, that no extraneous substance needs to be introduced, and that it affords the means of freeing many organic colloid bodies from impurities of the crystalloid class, which could not be removed by any

other method. It is hence a new power in the hands of chemists, and is extensively employed in Pharmacy and in Analysis.

Graham thus conceives of the theory of this remarkable process—Masses will not permeate the septum, but molecules only, moved by the force of diffusion. This septum, or hydrated colloid, gives up water, molecule by molecule, to the molecules of the crystalloid in the mixture. Such attraction being an inherent property of the crystalloid, the liquid medium required for diffusion is thus obtained, and the crystalloid is carried through the septum. A substance such as gum or other colloid, possessing a feeble affinity for water, cannot separate water from the moist septum, and so fails to open the door for its own passage outwards by diffusion. He illustrates the process by the well-known fact regarding a soap-bubble filled with carbonic acid and hydrogen,—neither gas can penetrate the water film; but the carbonic acid, being soluble in water, is condensed and dissolved by the film, and so passes out; while the hydrogen, insoluble in water, is retained within the vesicle.

The application of the process to the detection of poisons is obvious. Mr. Graham states, that all soluble poisonous substances, of whatever origin, are crystalloids, and can pass through colloidal septa, and be detected in quantities, from the four-thousandth to the ten-thousandth part of the mass. I am informed, however, by Dr. Fred. Penny, whose admirable skill in detecting poisons is so well known, that poison often occurs in solutions in quantities so minute, that it will not separate by this dialytic process, and yet can be detected by chemical re-agents.*

It was to mark their sense of the vast importance of these various papers on Liquid Diffusion—the Osmotic force, Diffusion applied to analysis, with the distinction of colloids and crystalloids, as advancing chemical physics—that the Royal Society, in 1862, bestowed upon Mr. Graham the Copley Medal.

In 1864, in the *Chemical Journal*, Graham enters into a curious speculation about the unity of matter. An atom is now considered to be the smallest combining proportion or volume—a molecule, the smallest portion, capable of existing in a free state. It is conceivable that there is only one kind of ponderable matter, but under a vast variety of forms and properties, owing to the molecular movement or state. Gold, lead, and iron may all be one in substance, only in different molecular conditions—and these, too, may be only oxygen, hydrogen, and nitrogen, &c., in other molecular states; or, again,

* Dr. Penny's lamented death occurred just three weeks after this address was read to the Society.

palladium on hydrogen, iron on carbonic oxide. Palladium, at ordinary temperatures, absorbs from 600 to 950 times its own volume of hydrogen, which does not part from it except under the influence of a high temperature; and the same holds for carbonic oxide and iron. The quantity capable of being introduced at a high temperature is small; but it is still present, and travels through the metal by a process like that by which carbon pervades iron in the formation of steel. He believes, indeed, that it is by the introduction of carbonic oxide that steel is made, and not by introducing solid carbon. The carbon, that is to say, must first be converted into carbonic oxide. It is then absorbed as a liquid by the colloidal metallic septa, and permeates the whole mass; and he maintains that the best way to make steel is to alternate the temperatures, by heating and cooling several times slowly, and thus giving abundant time for the permeation and combination. At a very high temperature the permeability of a palladium plate by hydrogen was very great, the velocity being enormous; but the plate was not permeable to any other gas.

Now, the peculiar action of hydrogen and the hydrides has much analogy to that of metallic oxides and chlorides, and a suspicion had long haunted the minds of chemists that this marvellous substance, perhaps the most singular in the whole range of inorganic nature, was a metallic vapour; and, in this view of its nature, Faraday long ago attempted its reduction to the liquid form by intense cold and pressure.

Against this view there is no antecedent improbability. Several metals volatilize readily, and the atmospheres thus formed are as perfectly pervious to the electric spark as common air or hydrogen, while three known metals have a specific gravity less than unity; and the most obdurate metals may be made to disappear wholly under an electric charge of great intensity, or a powerful burning-glass. The beams in the chimneys of refineries and smelting-houses get studded with crystals of gold and copper; and 15 per cent. of the lead would escape up the vent, if not arrested in its flight. (See Dr. W. Allen Miller's admirably lucid and most eloquent work on *Chemistry*, fourth edition, vol. ii., page 312.)

The powerful condensation of hydrogen by palladium brought out the strong probability that palladium, with its *occluded* hydrogen, was really an alloy; and as alloys have a peculiar set of properties in relation to those of the metals which make them up, Mr. Graham instituted a series of experiments to determine if the compound of hydrogen and palladium had such a class of properties—and he was completely successful. The physical, chemical, and magnetic properties, in their relation alike to the two components, and to other

substances, clearly shew that the compound is a true alloy. That the hydrogen can nearly all be driven off by a high temperature is no greater objection to its being a true alloy, than the fact that a high temperature will drive off zinc from brass, and leave only copper remaining. To the metal of which hydrogen is the vapour, Mr. Graham gave the name of Hydrogenium, in conformity with the usual nomenclature. He did not obtain it in a separate form, but he ascertained many of its properties. It is a little lighter than potassium, but heavier than lithium, the specific gravity being ·733. It must be solid, and have a white metallic aspect, and it must possess tenacity, and electric conductivity. The alloy is, however, easily made. On occasion of M. Dumas delivering last year in London an *eloge* on Faraday, a medal of this alloy was struck in commemoration of the event, and in honour of Graham, whose discovery had just been completed.

During the progress of the researches which led to this great discovery, another intimately related to it was made by Graham. To estimate aright the grandeur and interest of both, we must view them in connection with the revelations which the spectroscope had just made regarding the constitution of the sun and stars. He knew at this time that platinum, palladium, and iron absorbed hydrogen and carbonic oxide—"hydrogen *possibly in its character as a metallic vapour*"—and reflecting that if a piece of iron holding occluded within it carbonic oxide, were taken up by a chemist and analyzed, it would shew him in what kind of atmosphere the metal had been burnt, he began to wonder and inquire whether soft colloidal iron from regions beyond the earth would be found to contain any occluded gas—and if so, the gas would indicate the state of the atmosphere in which that iron had been burnt. Now, meteoric iron is extra-telluric; and hydrogen occurred to him as a probable gas, inasmuch as, shortly before this, the hydrogen lines had been detected in the spectra of the sun and certain fixed stars, in whose atmospheres also the incandescent vapour of iron and other terrestrial elements was known to exist. Does, then, meteoric iron contain occluded hydrogen, as it ought, if burnt in a hydrogen atmosphere? No time was lost in attempting to answer this question. He obtained a specimen of the Lenarto meteorite—an iron pure and malleable, without stony admixture, and analyzed it. His conjecture was fully verified! Out of this lump of meteoric iron he extracted three times its own bulk of gas, collected it in a tube, tested it as hydrogen, and burnt it! Now, this volume of gas is three times as much as that which, under ordinary atmospheric pressure, can be forced into

malleable iron. The metallic mass, therefore, must last have found itself in a state of ignition in a dense hydrogen atmosphere, whence it was extruded, and for which we must look "beyond the light cometary matter floating about within the limits of the solar system." It must have come to us from the far-off regions of interstellar space, "holding imprisoned within it, and bearing to us, the hydrogen of the stars!"

The results of these two inquiries, in which the train of thought and research pursued by Graham from the first find their culminating point, were as opportune in time as they were novel and grand. —The spectroscope reveals the astonishing fact that hydrogen is burning far out amid the stellar spaces. A fiery messenger from thence reaches this speck of earth in its long and rapid flight, and bears to the delighted vision of the philosopher a specimen of this very hydrogen of the stars, occluded in iron, as he had imprisoned it in his laboratory; thus confirming, by the faultless evidence of weight and measure, the wondrous fast-crowding discoveries of the spectroscope, and attesting, in the wide dispersion over the universe of the terrestrial elements, the Creator's unity in working and economy of power. Science has rarely achieved such triumphs as these; and seldom has there been a more fitting reward for a life-long earnest, humble scrutiny of Nature's mysteries, than the halo which they cast around the last days of Thomas Graham.

OTHER DECEASED MEMBERS.

Dr. Mathie Hamilton was long a member of our Society, and contributed papers to our journal. A year or two ago, from increasing infirmity, he was obliged to forego our meetings, which had always been to him a source of enjoyment, and resign his membership. His death occurred, however, in the present year; and it must not be that he should pass away without notice by us, though not a member at the time of his decease. Dr. Hamilton was in many ways a remarkable man. His energy and perseverance were so strong and untiring, that he rose superior to difficulties which would have crushed most men. His love of nature, enjoyment of natural scenery, keen and correct observation of the aspects of nature, and the social relations of the half-civilized races among whom he long sojourned, were unusually vivid and accurate, and rendered his conversation amusing and instructive, and his contributions to our knowledge of much scientific interest, as well as practical value.

Mathie Hamilton was born in Glasgow, on 18th March, 1793, and died in his seventy-sixth year, on the 22d April last. His parents and immediate relatives were in a respectable position in life, and of most honourable descent. His mother, Margaret Sanderson or Hamilton, was fifth in direct lineal descent from Elizabeth Knox or Welsh, wife of Mr. Welsh, parish minister of Ayr, and third daughter of the great Reformer, by his second wife, Lady Margaret Stuart, younger daughter of the Lord of Evandale and Ochiltree, second Lord of that title, and one of the distinguished "Lords of the Congregation." Lord Evandale's mother was the Lady Margaret Hamilton, only child of the Earl of Arran; and in this way Dr. Hamilton's family interlaced with the ducal house. He received his education at Glasgow College, for the profession of medicine; and in 1824, while yet a student, published, under the name of "Aliquis," a pamphlet on the procuring of subjects for the dissecting room, which received the warm approval of several heads of medical schools. The year following, he became a licentiate of the Faculty of Physicians and Surgeons of this city, and immediately after went out to South America, as surgeon to the Potosi Silver Mining Company. On arriving there, in company with the working staff, he found that the speculation had collapsed. He, however, remained in the country, and entered on a general medical practice. In this he succeeded beyond his expectations, and in a few years rose to the head of the Medical Staff of the Peruvian Army. After remaining in Peru about seven years, he returned home, and, instituting a suit against a member of the Company, received compensation for breach of contract. This and his other means he invested in house property in this city; but finding its management annoying to him, he sold it all off, and returned to Peru. Here he was well received by his former friends, and again enjoyed an extensive medical practice. About 1840 he returned home, and took out here his degree of M.D. During his residences in Peru, he visited many parts of the interior, and at other times made short excursions from Tacuna and Arica into the desert and mountain regions. Having a good knowledge of physical geography, geology, and meteorology, his observations possess a real value, adding something to our knowledge of these wild regions and their scanty populations. His contributions to medicine and the natural sciences were made through the Wernerian Society, the British Association, and our own Society. Some things were published independently. To the Wernerian Society he contributed a paper "On the larger Quadrupeds of South America—the Llama, Alpaca, Vicuna, and

Guanaco." It contains much interesting information respecting their habits, and valuable suggestions for their preservation, which were embodied in a representation to the native government, and had a good effect. Under the ancient Incas, these creatures were hunted into inclosures, by men and dogs encircling a wide area, and gradually drawing inwards. They were thus easily caught, shorn of their wool, and again let free, to be again collected and shorn, as we do with our sheep. But the modern Indians and Spaniards "kill the goose to get the golden egg." They hunt the animals in the same way, but make wholesale slaughter for the sake of the skin,—the reason assigned to Dr. Hamilton being, that the merchants gave a much higher price for the skin, because the wool cannot then be mixed with an inferior kind. Dr. Hamilton's suggestions led, I believe, to conservative measures on the part of the government in regard to these animals. With our own Government, and our representatives in those countries, Dr. Hamilton also had several communications in relation to the political and social questions of the time.

Not far from the scene of Dr. Hamilton's first labours there exists one of the most remarkable lakes in the world. It is 13,000 feet above the sea, 150 miles long, 70 broad, and of enormous depth. From its southern extremity a river takes its course, of 200 miles, into another lake, 60 miles long and 15 to 20 miles broad. Both are of fresh water; but there is no outlet for it—an exception to the law which holds in other parts of the world, that the water of closed basins is always salt. Now, the fact observed by Dr. Hamilton is this,—that a river not noticed by any traveller, or laid down on any map, issues from the south end of the southern lake; and as evaporation is very trifling over the whole region—a fact fully established by observations which Dr. Hamilton records—this river cannot be thus absorbed; but it cannot issue in any direction to the sea in an open channel, from the inclosed nature of the country; therefore must it descend into rocky caverns, whence it may again come out to the day far down beneath the mountains, and so find its way to the Pacific. If this hypothesis be correct—and it certainly seems in the highest degree probable—then the great Andean basin is not really closed, and thus is not an exception to the geographical law. As the Mississippi is the "Mother of waters," so, said Dr. Hamilton, is this great lake "Titicaha" the "Father of waters"—and not, as it is always spelt, Titicaca, which has a less pleasing and less poetic meaning. Aullagas is the name of the lesser lake. A descriptive account

of this region is published in our *Transactions*. In the *Edinburgh New Philosophical Journal* for January, 1841, Dr. Hamilton published a paper "On Earthquakes in the Western Parts of South America"—a valuable contribution, as being from the pen of a scientific man, who was an eye-witness of several of the terrible visitations in 1833 and 1834. An essay "On the Intermittent Fever of Peru" was published in this city, in a separate form, in 1842. In the report of the British Association for 1852, there is a paper by Dr. Hamilton "On the Lobos Islands of Peru," noted for their guano; and "Notices on Earthquakes," in the volumes for 1850 and 1854. Under the signature of "Aliquis," used in his earliest production, Dr. Hamilton contributed a number of articles to the *Glasgow Herald*, in relation to "Old Glasgow," after the manner of the well-known articles of "Senex," on the same subject. Portions of these sketches have been published in a work entitled *Glasgow Past and Present.*

Mr. Neil Robson was born in the district of Galloway in 1807. At that time his father was factor to a nobleman in the county, but soon after became occupier of a farm on the Eglinton estates, in Ayrshire. Mr. Robson was educated at the Irvine Academy, a school which has gained a well-deserved celebrity for its able teachers and successful pupils. At the early age of seventeen he started in life as apprentice to the profession of civil and mining engineering, under the late Mr. Smith, C.E., of this city. On the expiry of his term of service, he began business on his own account, and continued it for nearly thirty years, with constant employment and eminent success. In 1838 he married Miss Agnes Merry, daughter of the late Mr. James Merry, by whom he had a family of five children. In 1860, by request of the firm of Messrs. Merry & Cuninghame, ironmasters, he resigned business, and assumed the management of their extensive works; soon after he became a partner in the firm. His son, Mr. Robert Robson, and Messrs. Forman & M'Call, succeeded to his business. His son, however, soon withdrew from the partnership, and became a coalmaster. Mr. Robson died, after a short illness, in February last, at the early age of sixty-one. Among the larger works which he executed, I may mention the Glasgow, Barrhead, and Neilston Railway, the General Terminus Railway, the Caledonian and Dumbartonshire Railway, the Glasgow and Helensburgh, and the Lesmahagow Railways. The suspension bridge over the Clyde, in Glasgow Green, is also of his construction,—as is also the great diagonal bridge on the Barrhead Railway, near the South Side Park. His knowledge of our local geology was extensive and

accurate; and vast numbers of borings were undertaken on his recommendation, very rarely, indeed, without success. He was a leading Director of the Greenock and Ayrshire Railway, and for seventeen years Director and Deputy-Governor of the Forth and Clyde Navigation Company. Constantly engaged in a laborious profession, which kept him much away from home, he had little leisure for literary composition; and the only production that I know of which emanated from his pen, is an able and judicious pamphlet on the "Navigation of Canals by Screw Steamers." He was a member of the Institution of Civil Engineers in London, and of the Mining Institute of the North of England,—the meetings of which he often attended, and took part in the proceedings.

Mr. John Ure, a member of this Society almost from its origin up till the time of his death, on the 18th of November last, was born in this city on September 22, 1796. He was educated in Clugston's school, in St. Andrew's Square; and, having a taste for mechanics and chemistry, he attended at an early period the scientific lectures in Anderson's University, which have without doubt been the first beginnings of mental activity to multitudes to whom science would never otherwise have reached. This taste abode with him throughout a long life, which was divided between pursuits of this kind and the benevolent labours of a sincere and humble Christian. He succeeded to his father's business of a calenderer at an early age; but as it was long established, and he had a partner, he was little occupied with it, and he was left free to pursue more kindred objects, in the society of several friends of like tastes. Mr. Ure had the greater leisure for such pursuits, as he retired from business more than twenty years ago. His only invention, that I know of, is a machine for the ventilation of public buildings and factories, which I believe to have been very successful, and of which an account will be found in the third volume of our *Transactions.*

Dr. George Robertson, who died on the 11th July last, in his sixtieth year, was a native of Paisley. He was educated for the profession of medicine at our University. He was licensed to practice in 1836, and took the degree of M.D. in 1840. His first appointment was the charge of the South Albion Street Fever Hospital; after which he held a like office in Dundee. Returning thence, he opened Consulting Rooms in Glassford Street, and acquired celebrity in operations for *strabismus*, or squint, cutting for that defect having come into vogue about 1844. He was fearless as an operator, generally successful, and was resorted to from all quarters,—more especially as he exacted no fee from those who made any difficulty

about paying. For other diseases, also, he gave gratuitous advice, and his rooms were largely visited. One who knew him well has declared that the poor were ever attended to with the most tender encouraging sympathy and kindness, and medicines given away with unsparing liberality. We all know the distinguished benevolence towards the poor manifested by the medical profession of this city. Among them he was a conspicuous example; and this should be ever mentioned in honour of his memory. Its spring was in his large heart and generous sympathies; to gratify these and do good, was his delight. Doubtless, on some occasions, this kindness was carried to excess, and became injurious to the objects on whom it was bestowed; but no one ever doubted his motives. It was this excess of kindness alone, and no default in attendance or doubt of his skill, that produced those differences between him and the Directors of one of our public charities which led to his resignation of the important post which he there held. For a good many years he enjoyed a large and lucrative practice; yet he ever found time for his labours of love amongst the ailing poor. His memory will long be held by them in grateful remembrance. Dr. Robertson's married life was of short duration, his wife having died in 1848. His life thereafter was very solitary, as he had no children, or near relative, who could reside with him.

DISCUSSION ON PATENTS FOR INVENTIONS.

The subject of Patents for Inventions was discussed at three successive meetings of the Society, to which were invited a number of eminent inventors, engineers, manufacturers, patentees, and others interested in the question of continuing or discontinuing the protection of inventions. The discussion having extended to an unexpected length, the statements of the respective speakers are necessarily given in abstract in the following report.

December 1, 1869.—Mr. St. John Vincent Day, at the request of the Council, introduced the subject. After some prefatory remarks, he proceeded:—

I deem it necessary to say a few words at the outset as to the origin of patents for inventions, for this will in the speediest way enable us to perceive clearly the true spirit of such grants. Patents for inventions constituted one link in the chain of privileges of monopoly which the Crown, from ancient times,

enjoyed the prerogative of bestowing on any of its subjects; and this right of the Crown was exercised, we know certainly, as long ago as the period of the early Tudor sovereigns; but in the reign of Elizabeth, the royal privilege was so grossly abused that the state policy and right of the Crown in this respect were disputed. The action which the Queen herself then carried out in cancelling the obnoxious monopolies, and the satisfaction which she thus afforded the nation, are so well known that I need not dwell on them. It is, however, most important, in dealing with this subject, to bear in mind, that not against monopoly in the exclusive right conferred by patents for inventions was the public voice clamorous —indeed, it is only during the last few years of our own time that the policy of such grants has been questioned—but against monopolies and exclusive privileges for special trades, and by which grievous injury was done; indeed, the national policy, to say nothing of the individual advantages of granting patents for inventions, has always been most powerfully upheld.

In the succeeding reign of James I., the royal favour was again so grossly abused and unduly exercised, that, in 1623, the Parliament which then met demanded from the King that all monopolies established by royal authority should be null and void; and such was the effect of the representation of the House of Commons then sitting, that the King was forced to consent—the result being the passing of a celebrated measure, commonly known as "The Statute of Monopolies," in the twenty-first year of James I. This statute enacted that all monopolies, grants, and letters patent, for the sole *buying*, *selling*, *making*, *working*, or *using* of anything within the realm, were contrary to the laws and void; but whilst most stringent in other respects, it excepted all letters patent and grants of privilege for the term of twenty-one years then existing, and those for fourteen years or under thereafter to be made, "for the sole working or making of any manner of new manufactures within the realm to the true and first inventor and inventors of such manufactures, which others at the time of making such letters patent and grants should not use, so as also they *be not contrary to the law nor mischievous to the State, by raising prices of commodities at home, or hurt of trade, or generally inconvenient.*"

Nothing can be clearer than the last words of the foregoing clause, that the framers of the statute had in view the overthrow, for all time to come, of all those patents which at the time were in existence, or might afterwards be granted; also, the refusal to sanction any subsequently applied for, which in any way were or

that there is an Ether vibrating through all space, which moves the molecules, and causes all differences in properties.—But this is set forth as a mere speculation or mental exegesis.

I come now to speak briefly of the last, and in some respects, perhaps, the most brilliant, of Graham's discoveries. His researches on the subject were laid before the Royal Society,—the last paper only two months before his death. The discovery is but a grand climax in the train of thought which runs through all his principal memoirs, and guided his inquiries for a period of forty years. It was not so much the study of pure chemistry that engaged him, as the related parts of chemistry and physics. His first paper, on the absorption of gases, when he was twenty-one, led to his researches on gaseous diffusion; these led to liquid diffusion, and this again to dialysis and the theory of colloids and crystalloids, while this latter conducted him to his last brilliant discovery.

A film of India-rubber—such as little toy balloons are made of—is impervious to air or gas, but it has the power of liquefying the gases of which the air is composed. They penetrate its substance as liquids, and appear again on the other side as gases; but two and a-half times more oxygen passes through than nitrogen. The septum keeps back half the nitrogen, and allows the other half to pass through, with the whole of the oxygen. "The film is thus a dialytic sieve." This fact being discovered and known for some time, he seized upon a remarkable observation of two foreign chemists—Deville and Troost (*Proceedings*, Royal Society, 1868, page 427)—that hydrogen passes rapidly through plates of iron and platinum at a high temperature, and drew the conclusion that these and other metals liquefy and condense hydrogen, as the film of India-rubber does above mentioned. The strong mutual repulsion of the gaseous molecules resists chemical combination, and limits their power of passing into the minute pores of solids. These are more accessible to liquids than to gases; and it must be in the liquid state that they pass, becoming airs again if they make good their escape. The conclusion is fully warranted that the soft colloid metals, iron, platinum and palladium, have a dialytic action,—they have a "solution affinity,"—they act like septa in dissolving and absorbing gases, and have a power of separating hydrogen from other gases. A series of experiments, running through several years, and occupying three or four memoirs, establish this conclusion; and that these are almost the only metals which thus condense within them, absorb, or, as Graham termed it, *occlude* gases; while hydrogen and carbonic oxide are almost the only gases on which metals thus act,—

palladium on hydrogen, iron on carbonic oxide. Palladium, at ordinary temperatures, absorbs from 600 to 950 times its own volume of hydrogen, which does not part from it except under the influence of a high temperature; and the same holds for carbonic oxide and iron. The quantity capable of being introduced at a high temperature is small; but it is still present, and travels through the metal by a process like that by which carbon pervades iron in the formation of steel. He believes, indeed, that it is by the introduction of carbonic oxide that steel is made, and not by introducing solid carbon. The carbon, that is to say, must first be converted into carbonic oxide. It is then absorbed as a liquid by the colloidal metallic septa, and permeates the whole mass; and he maintains that the best way to make steel is to alternate the temperatures, by heating and cooling several times slowly, and thus giving abundant time for the permeation and combination. At a very high temperature the permeability of a palladium plate by hydrogen was very great, the velocity being enormous; but the plate was not permeable to any other gas.

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substances, clearly shew that the compound is a true alloy. That the hydrogen can nearly all be driven off by a high temperature is no greater objection to its being a true alloy, than the fact that a high temperature will drive off zinc from brass, and leave only copper remaining. To the metal, of which hydrogen is the vapour, Mr. Graham gave the name of Hydrogenium, in conformity with the usual nomenclature. He did not obtain it in a separate form, but he ascertained many of its properties. It is a little lighter than potassium, but heavier than lithium, the specific gravity being ·733. It must be solid, and have a white metallic aspect, and it must possess tenacity, and electric conductivity. The alloy is, however, easily made. On occasion of M. Dumas delivering last year in London an *eloge* on Faraday, a medal of this alloy was struck in commemoration of the event, and in honour of Graham, whose discovery had just been completed.

During the progress of the researches which led to this great discovery, another intimately related to it was made by Graham. To estimate aright the grandeur and interest of both, we must view them in connection with the revelations which the spectroscope had just made regarding the constitution of the sun and stars. He knew at this time that platinum, palladium, and iron absorbed hydrogen and carbonic oxide—"hydrogen *possibly in its character as a metallic vapour*"—and reflecting that if a piece of iron holding occluded within it carbonic oxide, were taken up by a chemist and analyzed, it would shew him in what kind of atmosphere the metal had been burnt, he began to wonder and inquire whether soft colloidal iron from regions beyond the earth would be found to contain any occluded gas—and if so, the gas would indicate the state of the atmosphere in which that iron had been burnt. Now, meteoric iron is extra-telluric; and hydrogen occurred to him as a probable gas, inasmuch as, shortly before this, the hydrogen lines had been detected in the spectra of the sun and certain fixed stars, in whose atmospheres also the incandescent vapour of iron and other terrestrial elements was known to exist. Does, then, meteoric iron contain occluded hydrogen, as it ought, if burnt in a hydrogen atmosphere? No time was lost in attempting to answer this question. He obtained a specimen of the Lenarto meteorite—an iron pure and malleable, without stony admixture, and analyzed it. His conjecture was fully verified! Out of this lump of meteoric iron he extracted three times its own bulk of gas, collected it in a tube, tested it as hydrogen, and burnt it! Now, this volume of gas is three times as much as that which, under ordinary atmospheric pressure, can be forced into

malleable iron. The metallic mass, therefore, must last have found itself in a state of ignition in a dense hydrogen atmosphere, whence it was extruded, and for which we must look "beyond the light cometary matter floating about within the limits of the solar system." It must have come to us from the far-off regions of interstellar space, "holding imprisoned within it, and bearing to us, the hydrogen of the stars!"

The results of these two inquiries, in which the train of thought and research pursued by Graham from the first find their culminating point, were as opportune in time as they were novel and grand. —The spectroscope reveals the astonishing fact that hydrogen is burning far out amid the stellar spaces. A fiery messenger from thence reaches this speck of earth in its long and rapid flight, and bears to the delighted vision of the philosopher a specimen of this very hydrogen of the stars, occluded in iron, as he had imprisoned it in his laboratory; thus confirming, by the faultless evidence of weight and measure, the wondrous fast-crowding discoveries of the spectroscope, and attesting, in the wide dispersion over the universe of the terrestrial elements, the Creator's unity in working and economy of power. Science has rarely achieved such triumphs as these; and seldom has there been a more fitting reward for a life-long earnest, humble scrutiny of Nature's mysteries, than the halo which they cast around the last days of Thomas Graham.

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Mathie Hamilton was born in Glasgow, on 18th March, 1793, and died in his seventy-sixth year, on the 22d April last. His parents and immediate relatives were in a respectable position in life, and of most honourable descent. His mother, Margaret Sanderson or Hamilton, was fifth in direct lineal descent from Elizabeth Knox or Welsh, wife of Mr. Welsh, parish minister of Ayr, and third daughter of the great Reformer, by his second wife, Lady Margaret Stuart, younger daughter of the Lord of Evandale and Ochiltree, second Lord of that title, and one of the distinguished "Lords of the Congregation." Lord Evandale's mother was the Lady Margaret Hamilton, only child of the Earl of Arran; and in this way Dr. Hamilton's family interlaced with the ducal house. He received his education at Glasgow College, for the profession of medicine; and in 1824, while yet a student, published, under the name of "Aliquis," a pamphlet on the procuring of subjects for the dissecting room, which received the warm approval of several heads of medical schools. The year following, he became a licentiate of the Faculty of Physicians and Surgeons of this city, and immediately after went out to South America, as surgeon to the Potosi Silver Mining Company. On arriving there, in company with the working staff, he found that the speculation had collapsed. He, however, remained in the country, and entered on a general medical practice. In this he succeeded beyond his expectations, and in a few years rose to the head of the Medical Staff of the Peruvian Army. After remaining in Peru about seven years, he returned home, and, instituting a suit against a member of the Company, received compensation for breach of contract. This and his other means he invested in house property in this city; but finding its management annoying to him, he sold it all off, and returned to Peru. Here he was well received by his former friends, and again enjoyed an extensive medical practice. About 1840 he returned home, and took out here his degree of M.D. During his residences in Peru, he visited many parts of the interior, and at other times made short excursions from Tacuna and Arica into the desert and mountain regions. Having a good knowledge of physical geography, geology, and meteorology, his observations possess a real value, adding something to our knowledge of these wild regions and their scanty populations. His contributions to medicine and the natural sciences were made through the Wernerian Society, the British Association, and our own Society. Some things were published independently. To the Wernerian Society he contributed a paper "On the larger Quadrupeds of South America—the Llama, Alpaca, Vicuna, and

Guanaco." It contains much interesting information respecting their habits, and valuable suggestions for their preservation, which were embodied in a representation to the native government, and had a good effect. Under the ancient Incas, these creatures were hunted into inclosures, by men and dogs encircling a wide area, and gradually drawing inwards. They were thus easily caught, shorn of their wool, and again let free, to be again collected and shorn, as we do with our sheep. But the modern Indians and Spaniards "kill the goose to get the golden egg." They hunt the animals in the same way, but make wholesale slaughter for the sake of the skin,—the reason assigned to Dr. Hamilton being, that the merchants gave a much higher price for the skin, because the wool cannot then be mixed with an inferior kind. Dr. Hamilton's suggestions led, I believe, to conservative measures on the part of the government in regard to these animals. With our own Government, and our representatives in those countries, Dr. Hamilton also had several communications in relation to the political and social questions of the time.

Not far from the scene of Dr. Hamilton's first labours there exists one of the most remarkable lakes in the world. It is 13,000 feet above the sea, 150 miles long, 70 broad, and of enormous depth. From its southern extremity a river takes its course, of 200 miles, into another lake, 60 miles long and 15 to 20 miles broad. Both are of fresh water; but there is no outlet for it—an exception to the law which holds in other parts of the world, that the water of closed basins is always salt. Now, the fact observed by Dr. Hamilton is this,—that a river not noticed by any traveller, or laid down on any map, issues from the south end of the southern lake; and as evaporation is very trifling over the whole region—a fact fully established by observations which Dr. Hamilton records—this river cannot be thus absorbed; but it cannot issue in any direction to the sea in an open channel, from the inclosed nature of the country; therefore must it descend into rocky caverns, whence it may again come out to the day far down beneath the mountains, and so find its way to the Pacific. If this hypothesis be correct—and it certainly seems in the highest degree probable—then the great Andean basin is not really closed, and thus is not an exception to the geographical law. As the Mississippi is the "Mother of waters," so, said Dr. Hamilton, is this great lake "Titicaha" the "Father of waters"—and not, as it is always spelt, Titicaca, which has a less pleasing and less poetic meaning. Aullagas is the name of the lesser lake. A descriptive account

of this region is published in our *Transactions.* In the *Edinburgh New Philosophical Journal* for January, 1841, Dr. Hamilton published a paper "On Earthquakes in the Western Parts of South America"—a valuable contribution, as being from the pen of a scientific man, who was an eye-witness of several of the terrible visitations in 1833 and 1834. An essay "On the Intermittent Fever of Peru" was published in this city, in a separate form, in 1842. In the report of the British Association for 1852, there is a paper by Dr. Hamilton "On the Lobos Islands of Peru," noted for their guano; and "Notices on Earthquakes," in the volumes for 1850 and 1854. Under the signature of "Aliquis," used in his earliest production, Dr. Hamilton contributed a number of articles to the *Glasgow Herald,* in relation to "Old Glasgow," after the manner of the well-known articles of "Senex," on the same subject. Portions of these sketches have been published in a work entitled *Glasgow Past and Present.*

Mr. Neil Robson was born in the district of Galloway in 1807. At that time his father was factor to a nobleman in the county, but soon after became occupier of a farm on the Eglinton estates, in Ayrshire. Mr. Robson was educated at the Irvine Academy, a school which has gained a well-deserved celebrity for its able teachers and successful pupils. At the early age of seventeen he started in life as apprentice to the profession of civil and mining engineering, under the late Mr. Smith, C.E., of this city. On the expiry of his term of service, he began business on his own account, and continued it for nearly thirty years, with constant employment and eminent success. In 1838 he married Miss Agnes Merry, daughter of the late Mr. James Merry, by whom he had a family of five children. In 1860, by request of the firm of Messrs. Merry & Cuninghame, ironmasters, he resigned business, and assumed the management of their extensive works; soon after he became a partner in the firm. His son, Mr. Robert Robson, and Messrs. Forman & M'Call, succeeded to his business. His son, however, soon withdrew from the partnership, and became a coalmaster. Mr. Robson died, after a short illness, in February last, at the early age of sixty-one. Among the larger works which he executed, I may mention the Glasgow, Barrhead, and Neilston Railway, the General Terminus Railway, the Caledonian and Dumbartonshire Railway, the Glasgow and Helensburgh, and the Lesmahagow Railways. The suspension bridge over the Clyde, in Glasgow Green, is also of his construction,—as is also the great diagonal bridge on the Barrhead Railway, near the South Side Park. His knowledge of our local geology was extensive and

accurate; and vast numbers of borings were undertaken on his recommendation, very rarely, indeed, without success. He was a leading Director of the Greenock and Ayrshire Railway, and for seventeen years Director and Deputy-Governor of the Forth and Clyde Navigation Company. Constantly engaged in a laborious profession, which kept him much away from home, he had little leisure for literary composition; and the only production that I know of which emanated from his pen, is an able and judicious pamphlet on the "Navigation of Canals by Screw Steamers." He was a member of the Institution of Civil Engineers in London, and of the Mining Institute of the North of England,—the meetings of which he often attended, and took part in the proceedings.

Mr. John Ure, a member of this Society almost from its origin up till the time of his death, on the 18th of November last, was born in this city on September 22, 1796. He was educated in Clugston's school, in St. Andrew's Square; and, having a taste for mechanics and chemistry, he attended at an early period the scientific lectures in Anderson's University, which have without doubt been the first beginnings of mental activity to multitudes to whom science would never otherwise have reached. This taste abode with him throughout a long life, which was divided between pursuits of this kind and the benevolent labours of a sincere and humble Christian. He succeeded to his father's business of a calenderer at an early age; but as it was long established, and he had a partner, he was little occupied with it, and he was left free to pursue more kindred objects, in the society of several friends of like tastes. Mr. Ure had the greater leisure for such pursuits, as he retired from business more than twenty years ago. His only invention, that I know of, is a machine for the ventilation of public buildings and factories, which I believe to have been very successful, and of which an account will be found in the third volume of our *Transactions.*

Dr. George Robertson, who died on the 11th July last, in his sixtieth year, was a native of Paisley. He was educated for the profession of medicine at our University. He was licensed to practice in 1836, and took the degree of M.D. in 1840. His first appointment was the charge of the South Albion Street Fever Hospital; after which he held a like office in Dundee. Returning thence, he opened Consulting Rooms in Glassford Street, and acquired celebrity in operations for *strabismus*, or squint, cutting for that defect having come into vogue about 1844. He was fearless as an operator, generally successful, and was resorted to from all quarters,—more especially as he exacted no fee from those who made any difficulty

about paying. For other diseases, also, he gave gratuitous advice, and his rooms were largely visited. One who knew him well has declared that the poor were ever attended to with the most tender encouraging sympathy and kindness, and medicines given away with unsparing liberality. We all know the distinguished benevolence towards the poor manifested by the medical profession of this city. Among them he was a conspicuous example; and this should be ever mentioned in honour of his memory. Its spring was in his large heart and generous sympathies; to gratify these and do good, was his delight. Doubtless, on some occasions, this kindness was carried to excess, and became injurious to the objects on whom it was bestowed; but no one ever doubted his motives. It was this excess of kindness alone, and no default in attendance or doubt of his skill, that produced those differences between him and the Directors of one of our public charities which led to his resignation of the important post which he there held. For a good many years he enjoyed a large and lucrative practice; yet he ever found time for his labours of love amongst the ailing poor. His memory will long be held by them in grateful remembrance. Dr. Robertson's married life was of short duration, his wife having died in 1848. His life thereafter was very solitary, as he had no children, or near relative, who could reside with him.

DISCUSSION ON PATENTS FOR INVENTIONS.

The subject of Patents for Inventions was discussed at three successive meetings of the Society, to which were invited a number of eminent inventors, engineers, manufacturers, patentees, and others interested in the question of continuing or discontinuing the protection of inventions. The discussion having extended to an unexpected length, the statements of the respective speakers are necessarily given in abstract in the following report.

December 1, 1869.—Mr. St. John Vincent Day, at the request of the Council, introduced the subject. After some prefatory remarks, he proceeded:—

I deem it necessary to say a few words at the outset as to the origin of patents for inventions, for this will in the speediest way enable us to perceive clearly the true spirit of such grants. Patents for inventions constituted one link in the chain of *privileges of monopoly* which the Crown, from ancient times,

enjoyed the prerogative of bestowing on any of its subjects; and this right of the Crown was exercised, we know certainly, as long ago as the period of the early Tudor sovereigns; but in the reign of Elizabeth, the royal privilege was so grossly abused that the state policy and right of the Crown in this respect were disputed. The action which the Queen herself then carried out in cancelling the obnoxious monopolies, and the satisfaction which she thus afforded the nation, are so well known that I need not dwell on them. It is, however, most important, in dealing with this subject, to bear in mind, that not against monopoly in the exclusive right conferred by patents for inventions was the public voice clamorous —indeed, it is only during the last few years of our own time that the policy of such grants has been questioned—but against monopolies and exclusive privileges for special trades, and by which grievous injury was done; indeed, the national policy, to say nothing of the individual advantages of granting patents for inventions, has always been most powerfully upheld.

In the succeeding reign of James I., the royal favour was again so grossly abused and unduly exercised, that, in 1623, the Parliament which then met demanded from the King that all monopolies established by royal authority should be null and void; and such was the effect of the representation of the House of Commons then sitting, that the King was forced to consent—the result being the passing of a celebrated measure, commonly known as "The Statute of Monopolies," in the twenty-first year of James I. This statute enacted that all monopolies, grants, and letters patent, for the sole *buying*, *selling*, *making*, *working*, or *using* of anything within the realm, were contrary to the laws and void; but whilst most stringent in other respects, it excepted all letters patent and grants of privilege for the term of twenty-one years then existing, and those for fourteen years or under thereafter to be made, "for the sole working or making of any manner of new manufactures within the realm to the true and first inventor and inventors of such manufactures, which others at the time of making such letters patent and grants should not use, so as also they *be not contrary to the law nor mischievous to the State, by raising prices of commodities at home, or hurt of trade, or generally inconvenient.*"

Nothing can be clearer than the last words of the foregoing clause, that the framers of the statute had in view the overthrow, for all time to come, of all those patents which at the time were in existence, or might afterwards be granted; also, the refusal to sanction any subsequently applied for, which in any way were or

might be productive of harm, either individually or nationally, which were not new, or were applied for by some other or others than the "first and true inventor." A careful investigation, too, of the clause further develops the underlying contingency—that in order to create such monopolies in no inventions but what were absolutely novel and advantageous, and to no other than the first and true inventor, the necessity was involved, prior to making the grant, of instituting a stringent scrutiny of all such applications for the exclusive privilege of a patent. Whilst, then, this was the true spirit or essence of the statute, yet it was imperfect, in that no provision was made for the proper examination of the applications prior to the letters patent being allowed; indeed, so imperfect was the provision for carrying out the true spirit of the law, and in practice so far was it from being acted up to, that the State was usually kept in entire ignorance of the true nature of what the applicant's alleged invention really was, as proved by the fact that the first specification enrolled bears date as late as October 3, 1711.* This defect, then, led the way to disputes as to the validity of several patents, and hence patent litigation became established, because it was the only course sanctioned by the Legislature by which the genuineness of the invention and its novelty at the time of making the grant, according to the spirit of the statute, could be deter-

* It is well to mention here, in order to make clear a point on which great confusion exists—namely, that the letters patent and specification are two distinct documents—that the letters patent do not describe the invention, but the title merely under which it is set forth in the specification. The letters patent bearing the Great Seal have always been used by the Crown in making a grant to an inventor; and before the year 1711, the inventor was merely required to declare his invention by a very vague inventory. These inventories have recently been collected together in a volume by Mr. Dircks.

The following note respecting the origin of enrolling specifications of patent inventions is from the Report of the Select Committee of 1829, page 170:—

"Near the end of the reign of Queen Anne it became the custom to insert a proviso into all patents, to oblige the patentee to execute a complete specification of the invention for which the patent was granted, and also to enroll the same in the Court of Chancery, within a specified time after the date of the patent. Before that time, the patentee was not called upon for any specification; Mr. Savery's patent of 1698 has no such clause. The inconveniences of giving the patentee a privilege, without defining the object to which it extended, are obvious; nor could the public have had any security for obtaining the invention at the expiration of the patent. The authority by which this clause was introduced does not appear. It was not a Parliamentary measure. When Parliament gave a reward to Sir Thomas Lombe, in 1732, for silk machinery, a model was deposited in the Tower of London, where it still remains."

mined. Another result of this great oversight of the framers of the statute has been that, from time to time, numerous deceptive and positively obnoxious patents have been and still continue to be granted. It is a fact, that not only are letters patent granted for the same thing over and over again, but frequently for the most absurd and impracticable projects; and, what is even worse, numerous patents are every year granted which infringe existing rights, which infringe unexpired patents in many cases for precisely the same thing. In illustration of this, I could point you to one or two notorious instances without going far from these walls. Nor is this avoidable, without a strict examination into the specification and claims of every patent before it is allowed.

Since the passing of the first statute, on which letters patent for inventions are based, the law has been several times amended, and held to extend to improvements in existing processes, manufactures, machines, and so on; experience having pointed out that, whilst absolutely "new manufactures" or processes are of rare occurrence, improvements of vast importance in or upon existing manufactures, processes, or machines, are very numerous; and as late as 1852, the Amendment Act under which we are now working came into force. That Act contains provisions for the examination of the documents accompanying each application for letters patent; yet the examination, based on a mere outline of the invention, is of such a nature as not to afford any certainty whatever that the letters patent granted are valid. It is, in fact, a "look through," by one of the law officers of the Crown, of the provisional specification accompanying the petition,—a document which usually in a meagre way sets forth the nature and objects of the invention, without minutely detailing how it is put into practice, and according to the information contained in which the law officer may either grant or refuse, or require the applicant to amend it; whilst, as regards the all-important document, the specification itself, the inventor is left to his discretion, for with it the Crown does not interfere until tested in the law courts. It is perhaps hardly necessary to add that this freedom, in the hands of an unscrupulous patentee, is often most unfairly taken advantage of, by enabling him, on the one hand, to file such a specification as conveys no exact notion of the particular invention, or, on the other hand, to make claims for that to which he is not entitled; indeed, leaving it to the patentee's discretion whether to define his invention by claims or not; and thus aiding the patentee to extort royalties which legally are not due, merely because in so many instances manufacturers, and others

who use the patent, cannot afford the time and money to dispute the validity of a vested right. This liberty, as to the claims of a patent specification, is undoubtedly the cause of oppression and extortion to a most unjust extent, and to obviate it must be one of the provisions in an amended law.

I repeat, then, that the true spirit in which letters patent for inventions were originally devised, has never been acted up to. Doubtless, too, under the past and present state of administering the law, and in later times, under the Patent Office, this true spirit could not be enforced at the time of making the application; but it remains yet to be shewn whether, by an efficient employment of the means at our disposal, the novelty of each alleged invention, for which letters patent are applied, cannot be so far determined, as to stamp it at once with so considerable an approach to validity or otherwise, that the grounds on which letters may be granted or refused shall seem so reliable, that the public may feel so much confidence in what is granted or refused, as will place both it and the inventor on a much surer footing than they now occupy. If proof be wanted that this may be effected, I have but to refer to the American Patent Office, where on the average about 20,000 patents are applied for every year; and the Chief Commissioner, Fisher, has recently reported that out of every three applications one is refused. Such is the result, in that country, of the careful examination, with reference to pre-existing documents and existing patents, which each specification undergoes, before the letters patent are allowed.* There is no country in the world wherein the rights of inventors are so carefully guarded by the State as in America. The examination which the invention undergoes before being allowed, stamps it with so large a degree of certainty, that infringement is reduced to a minimum, and the right of property is duly recognized. If all this good result, then, is effected in a country where at least five times the number of applications are yearly made that are made in the whole of Great Britain and Ireland, surely our eyes cannot be shut to the duty which lies before us of using our endeavours to promote some such course at home. The American system, too, is attended

* In the Report of Hon. S. S. Fisher, Commissioner of Patents, for the year ending September 30, 1869, the following figures appear:—Receipts, $686,388.62; expenses, $472,462.60; excess of receipts, $213,962.02; applications for patents, 19,360; caveats, 3,686; applications for extensions, 153; extensions granted, 125; patents issued, 13,672; patents issued, but withheld for the payment of final fees, 899. The number of patents issued during the year is 481 less than during the previous year.

with far less expense than our own,—it being a very wise provision in the Act of Congress, that the expenses of the Patent Office shall not exceed the receipts; indeed, it is but just that if inventors are to give their time, labour, and means, in working for the national good, that the portion which they pay to the State in appropriating the invention to themselves for a limited period, should by the State be expended in rendering the property or right conferred for that period as secure as possible. In Great Britain, however, there is every year an enormous surplus from Patent Stamp duties,—between £40,000 and £50,000 sterling, directly contributed by inventive talent. This is paid into the Treasury, in place of being used for the benefit of the inventor, as it ought to be; indeed, it is not too much to say, that if the present Commissioners of Patents were provided with a sufficient number of practical and scientific examiners, one with assistants being appointed to take charge of each class of invention, that with the magnificent library and collection of documents which the State possesses, placed in a suitable building where all would be accessible for use, patent property would be as safe here as it is in America, infringement would be reduced to a minimum, and interfering patents would not exist. The great thing to be ascertained by such examiners is the *novelty;* it would be absurd to expect them to determine whether the patent should be allowed or not on the ground of its value or insignificance. That can never be known until it is put to the test of practice; but one thing is clear, that several very foolish patents which are yearly applied for—absurdities, such as machines for producing perpetual motion, flying in the air, &c.—would by such a system be peremptorily refused.

(Mr. Day then adverted to the effort for abolition lately made in the House of Commons, and the prospect of its being repeated; and after referring to the obligation devolving upon the Society, from the character of many of its members as inventors, patentees, and men of science, to resist such attempts, addressing the President, he continued:—)

The remarks, Sir, which fell from you in your recent inaugural address, wherein you stated the necessity of protection to inventive talent, gave a pretty clear expression of the views which we know to be held generally by those who have given themselves to deal fairly with the subject; neither did the President of our kindred Institution—the Institution of Engineers in Scotland—omit to state, in very decided terms, expressions of a like nature; and certainly what has fallen from both may be taken as the index of

fact, and decidedly exponential of the reception with which any proposals for patent abolition will be met on "this side the Tweed."

Let us, then, examine into the abolitionist's stronghold, upon which he seeks to destroy the rights of inventors. He starts upon the assertion "that they are monopolies; that, as such, they are odious and hurtful, are noxious weeds in the fair field of industry, clogs on the smooth wheels of commerce." The abolitionist body, which does not, I believe, number many really significant names, contains some gentlemen who have profited largely in business, partly from having adopted some most important patented apparatus, but who, in some of their connections with patents, not having been quite so fortunate as they desired, proceed at once, from their own special case, to condemn the entire policy of a patent law.

The abolitionist party does not deal in facts at all that are of the least weight from a national point of view; and we must remember that it is far more of a national than an individual matter which we are met to discuss; and let us not forget to sink individual considerations, as of second importance to those which affect us as a nation. The abolitionists take it up as a manufacturer's question solely; they deal only with theory unsupported by facts, whilst they have not looked at the matter at all from an opposite point of view. They suppress all evidence favourable to views opposed to that of abolition. In short, the abolitionists are fighting for the manufacturer, and against the public—the nation—and therefore their denunciations are groundless, idle, the mere assertions of unsound fancies. I think I may truly say, without offence to any one, that we challenge those gentlemen to point out a single fact brought forward in any part of the evidence before the Royal Commission, that in the least degree bears against the policy of patents, or exhibits their alleged injury to trade and commerce; and we may further challenge the abolitionists to shew, on trustworthy grounds, one single point in all that has been written or said, which is other than direct proof of the national as well as individual importance of a judiciously administered patent law.

Let us now consider some of the grounds upon which the abolition of patents for inventions is urged. On the ground of what the abolitionists call "natural rights" of property in invention, it is declared an inventor has but two "natural rights," the right to use his invention and the right to conceal it; and that, while the State is bound to protect the inventor in the free exercise of his right of *use, it should,* on the other hand, *"maintain the natural right of all*

its citizens to do whatever they please, provided it wrongs nobody." I humbly ask for evidence shewing that the use of another's invention —which we well know in every case has cost the inventor much time and labour to bring into a practical condition, and in most cases has also cost him, in addition to his time and labour, a serious sum of money—I ask the abolitionist to shew how its free use by the public would wrong nobody? Would not the inventor be wronged? Would he not be positively and most cruelly cheated? Has the abolitionist made himself aware of any of the numerous cases of inventors who were thus robbed of the fruit of whole years of labour, when, under the old law, the obtainment of patents was so costly that none but capitalists could embark in them? Does the abolitionist call to mind the numerous cases of men who have benefited the world so largely by their inventions, but who, for want of proper protection being secured to them, were frequently reduced to starvation and even death, and yet say that these men were rightly dealt with? Inventors may, indeed, be thankful that in later times, under the amended patent laws, their rights are more efficiently recognized than they were in the past darker ages. To talk of patents being wrong because they confer a monopoly, and are opposed to "natural rights," is simply to talk nonsense.

Indeed, if we are to deal at all with this side of the question, I should say, and know well the majority will say with me, that every invention is "by nature" a monopoly, whether we have a patent law or not; because, in the very nature of mental planning and origination, every invention is the inventor's own possession *solely* as long as he chooses to confine the knowledge of it to himself for his own behoof and benefit, or to any number of others for their joint behoof and benefit. Yet experience on all hands proves that inventive monopoly of this nature, that is to say, *secretly* employed, is productive of the *least* advantage to the inventor, and is not unfrequently injurious to the public, and I should like the abolitionist to point out, if he can, that by the patent system both inventor and public are not immensely benefited, for he must show *that* amongst numerous other disadvantages, if he expects an inventive British nation to assent to his dictum of total abolition.

The framers of the law most wisely devised it so that the *maximum* advantage should be secured to the nation, by allowing the inventor the stimulus of its exclusive use and exercise for a certain number of years, in order that at the end of that time it might be secured to the public, in return for the benefit conferred upon the inventor over a limited period; by requiring him to file a complete specification

of his invention, and the manner of putting it into practice, of whatever nature it might be. Indeed, while recognizing every man's right to the *materially embodied results* (not the mere ideas on paper, bear in mind) of mental origination, experiment, expenditure of time and money, the State's chief object, under the patent system, has been to secure the invention to the nation. And I suppose it is hardly necessary for me to ask you to look around this great city—with its weaving and spinning mills, its iron works, forges and rolling mills, its ship yards and engine works, its alkali works, its oil works, its sugar refineries, its calico-printing and Turkey-red dye works, its potteries and glass works, its paper mills and its corn mills—it is barely necessary to ask you to look at the ships in our harbour or the locomotives on our railways—and to inquire if all this teeming industry, all this wondrous productive ability, forcibly tells us whether we have profited or not by securing to the nation the thought, the foresight, the skilled plans, the cunningly-wrought devices of such men as Lewis Paul, Thomas Highes, and Richard Arkwright, of Hargreaves, of Kay, or Heilmann, or Lister, of Dudley, Cort, Beaumont Neilson, Siemens, or Bessemer, of Joseph Whitworth, Richard Roberts, or James Watt, of Robert Napier, Penn, or the Maudslays, Rennies, Stephensons, and Fairbairns, or James Young; and does the work, the offspring of their labours, prove to us that we should have been better off, and as far on in the race towards the acmé of economy and productive capability, but for the stimulus and value imparted to inventive talent by a patent law?

(Next, referring to the views of Professor Thorold Rogers, of Oxford, who has affirmed that "in ninety-nine cases out of a hundred, the patentee is only a simultaneous inventor with a number of others, who lose their labour and ingenuity because one man happens to get in first," MR. DAY asked :—)

Where are the proofs that in *ninety-nine cases out of every hundred* the patentee is only a simultaneous inventor with others? At this place it is sufficient to contradict the assertion as being wholly untrue. That it sometimes happens that a similar result is elaborated by more than one individual is perfectly true, and sometimes simultaneously; this is only the natural consequence of a public's demand for something which it does not already possess as readily as it desires, or that which already exists does not suit the public taste, or that something totally new is asked for; but in this, as in every other mode of meeting a public want, why is not the man of greatest enterprise—he who is foremost in the race—to reap the *greatest benefit*, which, as in every other transaction or pursuit, is

what all who work at it labour after? Where there is a prize to be won, surely it is due to him who first fulfils the conditions on which it is to be possessed, quite independently of any question as to the number of competitors.

I do not mean to argue but that licenses should be compulsory,—I certainly think they should be; and if that were enacted, it would have the effect of reducing royalties to a fair value, because any one applying for a license, in the event of a refusal, would then have an appeal to some court of law, where the grounds of refusal would have to be stated, and the judge would, upon the facts produced, legislate as to the royalty the patentee would be entitled to demand.

If property in the results of matured thought, of experiment after the expenditure of time and means, is essentially wrong and inflictive of injury upon others, why, then, it is equally wrong to possess property of any kind, because, if the possessor is better off than his neighbours in one case, he must also be in the other. The abolitionist, in order to be consistent, must equally urge that yonder owner of landed property, or house property, of capital realized out of speculation, or a careful watching of commercial trading and enterprise, must at once give it all up, after his years of labour, for the benefit of this or that man, simply because, in the nature of things, had the others been similarly placed, each might have achieved the same results; the abolitionist would not debit the shrewdness, the tact, the forethought and constant watching of time, circumstances, and events by which the results have been effected, with any share in the profits.

"The public, the millions, have a greater interest at stake in the maintenance of a patent law than they are aware of, because its importance has not hitherto been brought under public notice. To abolish patent law means to depress and almost to stifle competition in all trades and manufactures; and just as manufacturers have over and over again combined to enter upon expensive legal processes to thwart the right an inventor has obtained from the Crown through the medium of letters patent, so also might they at any time combine to maintain high prices for articles of universal consumption;" * so that positively patent protection is a check against combination of the manufacturers—is a power in the hands of the public to keep down the prices of articles to a reasonable uniform standard.

Argue as we will, start from whatever point of view we may, one

* *Letter to Lord Stanley*, by H. Dircks, part ii.

thing is evident, that in order to secure inventive talent for promoting the national good, we must hold out reward to the inventor; the abolitionist, even, owns that the inventor should not go unrewarded. Invention, we have abundant proof in those countries where there is no patent law, is not productive of national advantage, and precisely from the lack of stimulus which the patent law affords; for example, when do we hear of an important invention coming to maturity in Switzerland, where there is no protection for inventors? yet this is not because there is no inventive talent in the Swiss, but purely and simply for the reason that there they cannot employ it to advantage, and have to come here or go elsewhere, where inventive talent is legally recognized, in order to secure that reward which the public appreciation of the invention indicates as the due value. It being on all hands, then, admitted that the inventor must be rewarded, we have next to consider what means are available for securing the reward; and, of those means, which is the best for both the parties concerned,—the nation, and the inventor.

As to available means of reward, I know only of two that can in any way be dealt with—namely, State rewards, or that which is secured by a patent law. Of the former we have some knowledge; it has been tried, found wanting, and is now an exploded delusion. At one period the State rewarded inventors by payment of a sum of money, sometimes with, and sometimes without, the addition of a patent, and the chief effect of it was to directly encourage fraudulent and misdirected ingenuity; as is proven by the Appendix to the Report of a Select Committee of the House of Commons, who examined the patent laws in 1829.

We are brought, then, to conclude that the patent system is the only one by which the nation can secure the maximum advantage from invention, the only one by which invention is properly encouraged, the only one by which the real value of an invention can be ascertained, and, therefore, the only one which can secure not merely a reward, but a due reward—precisely its exact worth—to the inventor.

Whilst, then, no fault is inherent in the theory of the present law; whilst theoretically, indeed, it is precisely the right thing; and when, under certain grievous defects in present practice, the country has so unprecedentedly advanced, and individuals have so largely benefited, it must be abundantly apparent that, if that law is only put on a more equitable basis for its administration, by which the *existing* anomalies and errors would be wiped out, then the real

result can only be a still greater progress in those advantages. To say that the time has arrived when, in the interests of trade and commerce, it is proper to tear asunder the link which has enchained invention to the British nation, is simply intolerable; it is, as Whately wrote, like "those who, having magnified into serious evils, by injudicious opposition, heresies in themselves insignificant, yet appeal to the magnitude of those evils to prove that their opposition was called for,—act like unskilful physicians, who, when by violent remedies they have aggravated a trifling disease into a dangerous one, urge the violence of the symptoms which they themselves have produced in justification of their practice."

We have had experience, in former times, of patents at a great cost, and, more recently, of patents at a reasonable cost, and that experience shews that under the old system of costly patents a great part of the real value of invention was lost to the country; the great expense to obtain the needful property in an invention, in order to render it of public benefit, became often a barrier to realizing the property. Not unfrequently it was productive of crime, by stimulating the abomination of *secret* working.

All this has, in a great measure, been set aside by the comparatively cheap patents granted since 1852. The abolitionist, however, would not even amend the present law, but positively proposes to eradicate protection to inventive talent altogether.

If the gentlemen who so urgently pursue the cry of abolition would help us to amend the discrepancies in the present law, we should then have no fault to find with them. As a nation which lives so largely upon the returns secured to us by the protection granted to the embodied results of inventive genius,—a nation which not only lives, but influences the whole world thereby in so many ways, which scatters the direct products of its inventive talent to feed and clothe, to teach, and emancipate from the thraldom of ignorance the sons of toil in every clime,—a nation which, by the very essence of invention, influences so effectively the march of civilization, and, in return, brings home to her own door such gains; —I say, then we could tolerate these gentlemen, who, no doubt, as they are now working, believe themselves to be our best friends, for the assistance which, in such a position, they would be able to afford us.

And in order to appreciate the importance of nursing invention, we need not go beyond our own precincts. I should like the abolitionists to tell us where our iron manufacture would have been but for Beaumont Neilson's hot-blast patent? or where the steam

engine itself would have been but for James Watt's patent? where our weaving or spinning mills would have been but for the stimulus held out by patents to the endless numbers of inventors who have worked therein, and the intrinsic worth of which, in a national sense, it is beyond our power to estimate? And what shall I say of steam navigation, which was brought into existence at our very doors; or of the vast improvements in shipbuilding, which have placed the Clyde in the van of this industry? Need I further allude to our sugar refineries, with the number of important patented inventions at work there; or shall we look to the potteries and glass works, and the innumerable chemical works; and will it be said, in face of all this, that the protection afforded to inventive talent is virtually wrong, is intrinsically pernicious, and productive of wide-spread injury to mankind? Let us take the reverse view, and for a moment suppose that we had had no protection, what would have been the result?—namely, this, that whereas there would then have been no such stimulus to inventive talent, we should have had no alternative but to make the most we could out of existing ways and means, as it would not profit us to make a step in advance if, to effect that, we must first expend often an enormous capital to prove and perfect our invention, and no sooner to have it perfected than to see, as the only result, our neighbours on all hands take advantage of our labour, time, and money, without let or hindrance; whilst the inventor himself would have to work with it as best he could with crippled means,—not to profit, bear in mind, but first of all to repay himself that which he had expended for the benefit of his fellow-men, but loss to himself.

Does any one suppose that invention would be recognized, or could flourish in a country where such a state of matters existed, and it is to such a condition that the abolitionists would reduce us; or that any one would commit himself to such an act of loss as the elaborating and perfecting of an important invention involves, merely to get as his reward the fleeting, unsubstantial honour of being called "the Inventor"?

I would, if time permitted, bring forward many more such arguments not less powerful; but I am sure that the citizens of Glasgow have too much good sense not to comprehend the justice of, and absolute necessity for, a judiciously administered law for protecting the inventive talent of the country.

So far as our requirements, comforts, and independence are concerned, I cannot, for my own part, see to what other faculty of *the human* mind we primarily owe so much as to invention; for go

where we will, try our hand at whatever we may, we cannot get out of its influence. Through securing and cherishing invention is it that our bodies are clothed and housed; our roads reclaimed from the mud-track; our railways, steamships, and telegraphs carrying us and intelligence of all kinds at such speed as to make the most of time. The success, too, of the trader, to a large extent primarily depends upon the direct products of that faculty; the national revenue is vastly affected by it. When, then, this one mental faculty has primarily been the means of elevating our land and people to so lofty an eminence—when individuals cannot avoid depending on it—surely we should pause ere we commit ourselves to the wholesale abolition which the promoters of this new scheme so vehemently contend for.

In concluding, Mr. President, after a very incomplete exposition of some only of the vital points which demand our attention, and having made no allusion to the copyright analogy, which, I trust, will now be fully developed in discussion, I will only repeat some rather forcible words which have recently been used in a certain high quarter, and appear to meet our present case with exceeding fitness—namely, not to forget that, "whether we are Radicals or Conservatives, we require to be reminded that truth or falsehood, justice and injustice, are no creatures of our own belief. We cannot make true things false, or false things true, by choosing to think them so. We cannot vote right into wrong or wrong into right. The eternal truths and rights of things exist, fortunately, independent of our thoughts or wishes, fixed as mathematics, inherent in the nature of man and the world. They are no more to be trifled with than gravitation. If we discover and obey them, it is well with us; but that is all we can do." *

Dr. Bryce, the President, proposed the following motion, and expressed a desire that the discussion might be founded upon it, but remarked at the same time, that any member of the Society had a right to move an amendment:—" That this Society, whilst recognizing the benefits that have accrued to inventors and to the public from the operation of the new Patent Law, since the Amendment Act came into force in 1852, considers that the law is in several respects defective, and, whilst pledging itself to use all the means in its power to oppose the total abolition of the law, will lend an earnest, strenuous, and active support to any well-advised scheme of amendment."

Dr. F. H. Thomson, Vice-President, seconded the motion.

* J. Anthony Froude's Rectorial Address at St. Andrew's University, 1869.

Mr. Edward C. C. Stanford.—There is no subject on which greater unanimity prevails, than the necessity for reform in our patent laws, but, at the same time, there is no subject on which greater diversity of opinion prevails, than how that reform should be carried out. The question naturally divides itself into two—namely, What shall be the best means of protecting the invention, so as to give the greatest amount of benefit to the public, and, at the same time, reward the true and real inventor of the discovery? As to the first point, I must say that I never could sympathize with those who have been described here this evening as abolitionists. I cannot see how these men can hold that while, on the one hand, any one has a perfect right to Government protection for a poetical idea,—stamped on paper in the form of a poem,—on the other hand, one has no right to Government protection for a mechanical idea stamped on an engine, or for a chemical idea stamped on some new process of chemical manufacture. I do think it is rather too bad that one kind of idea should be at once protected by Government, whereas another kind of idea should not, especially when, as it often happens, a poetical idea may be exactly worth the paper it is written upon, and no more—may be, in fact, far more suitable for external application to our groceries than for internal application to our minds. Another point is,—Suppose the patent laws were abolished,—suppose, for instance, a man invented a particular machine by which a particular manufacture could be carried out at half the expense,—suppose it were impossible for him to obtain protection for that discovery, the result would undoubtedly be, that the man would maintain it a perfect secret. In that case, the public would acquire no benefit whatever; whereas, if he were allowed to protect his discovery, not only would he himself reap the result of that discovery, not only would he be able to cheapen his production by 50 per cent., but the whole nation, even the whole world, would do the same. These are such strong points, that I do not understand how any form of total abolition of protection can be carried out. At the same time, no one is more sensible than myself of the very great need there is of reform in our present Patent Office. There is no man who has visited for an hour or two that remarkable collection of curiosities—perhaps the most remarkable in Great Britain—in the Patent Office in London, that will not admit there is a crying need for reform. If it is, as I assume it is, advisable that protection should be accorded to all discoveries, then I think it follows, as a natural *result, that* it should be conducted and accorded as cheaply as

possible. It does appear to me that the present patent fees are totally opposed to inventions in this country. They are certainly very largely opposed, and almost prohibitory, to those large classes from which we draw our best inventors,—the working classes of this country. I quite admit that the expense of taking out these patents should be saddled upon the patentees, but I don't understand why Government should be allowed to gather, as I believe they have at present, about £650,000 of surplus, over and above the expense of the patents. I do not understand, either, why they should keep a large staff, at a cost of some £16,000 a year, nominally and professedly to inquire into patents, whereas every one knows I may patent a thing to-day, another may patent the same to-morrow, and somebody else next day. There is actually no supervision, practically speaking. I would, in the first place, make the expense of protecting a discovery as cheap as it possibly could be made. I would simply have it that Government should charge for that protection exactly what it costs, and no more. But, while on the one hand I would make the protection as cheap as possible, I would make the obtaining of patents as difficult as possible. I would have this staff a really properly conducted staff—a staff which, as Mr. Day has spoken of already, should be composed of a certain number of men who had really talent and experience in patents. Perhaps this might be productive of occasional injustice. Probably there might be some discovery on which this committee might have some difficulty—(parenthetically, I would ask, Have we a single judge who can administer proper justice in all patent cases? I think we may say at once we have not);—but, at any rate, the appointment of this Commission would have this effect,—it would prevent any one from taking out a patent that had been taken out before. That is an important thing. It would, to a very great extent, I believe, as Mr. Day has already said, prevent litigation, because that committee should be so well composed, and should be able to form so accurate an opinion of patents, that no man could take it up afterwards as a matter of litigation; and it would certainly have this effect, that in place of patentees being considered, as they are supposed to be, shallow-brained idiots, with more money than sense, as any man might say who spends a day in the Patent Office,—(it is a sad reflection on our national credit and national education!)—we would, at any rate, insure that our patentees should be, as they ought to be, the scientific men of the country.

Mr. Macfie, M.P. for the Leith Burghs, having been invited to

take part in the discussion, was then introduced by the President. He said:—

Dr. Bryce and gentlemen, I have to thank you for the favour you have done me in allowing me to be present at this discussion on a subject of the utmost importance, and one in which I myself have felt great interest, and in the discussion of which I have taken some part,—and, God sparing me, mean to take part still. I would not conceal the disappointment I feel that, in the city of Glasgow, and in the Philosophical Society of the city of Glasgow, a paper, such as that just read—an able paper, an honestly written paper—should have been asked for by the President and Council of that Society. I look at the history of Glasgow, from the time of Adam Smith, the head and fountain of all sensible political economy. I don't find that he says a single word on behalf of patents. If he has said a word, let any gentleman tell me. I know that in M'Culloch's edition of *The Wealth of Nations* considerable stress is given to the advocacy of patent monopoly, in a note; but I don't find it in the text of the great political economist himself. I find that one of your most eminent citizens writes one of the very best papers that ever was written upon the subject of patents, and advocates their total abolition,—I mean Mr. James Stirling. I find one of the most eminent living natives of Glasgow, a late candidate for the representation of the Universities of Glasgow and Aberdeen, is in favour of abolishing patents; and I hope that next session I will receive the support of another eminent Scotchman, Professor Lyon Playfair. I have been asked to take part in the discussion of a motion proposed in opposition, as I believe, to the views of some of the most eminent economists of the day, in a Society founded, as I see from one of the diplomas, for the promotion of science. I opined, if this subject was to be discussed, it would be considered upon scientific principles. I thought you would have considered philosophically what are the reasons that can be adduced on behalf of this monopoly. I don't find in the paper much that I would call logical argument. I find a great many assertions, many things that I could controvert; but I would rather not take part in a discussion where there is such a decided prejudging of the case in the ruling power here.

The President.—There is no prejudging of the case. The question is perfectly open. Mr. Day is alone responsible for the opinions he has expressed.

Mr. Macfie.—In justice to myself and one or two bodies and individuals, I will trespass upon your time for two or three

minutes, thanking you for the opportunity you have afforded me. After a brief reference to his proceedings on the question in Parliament, Mr. M. proceeded:—I do not undervalue inventions. I would do everything I could to stimulate inventions; but I believe that the system of patent monopoly is the very worst possible for the interests of the nation, and for eliciting inventions, and combining inventions. By all means stimulate; but stimulate by direct State rewards, and not by giving individuals the power of seizing monopolies injurious to their fellow-countrymen for fourteen years. One of the reasons which induced me to come to this conclusion is, that other nations are throwing away the trammels of the patent system. Switzerland never had one; Holland has just fixed on the abolition of hers; Prussia gives very few patents, and yet Count Bismarck has lately brought forward, on the part of his Government, a resolution, which will be carried before long, for the total abolition of patents in the North German Confederation. In these circumstances, I ask, how can the manufacturers of Glasgow compete with manufacturers on the Continent who are freed from the restrictions of patents, from the burden of paying for patents? That they are a restriction is as plain as daylight. It is a fourteen years' prohibition to use every invention that is patented, unless you pay a considerable sum of money to its inventor. Take an illustration from the iron trade. I have been at pains to ascertain what I am speaking about, and believe I am not wrong in my facts. I know that in a particular case Mr. Bessemer refused the right to use his patent inventions to a company in England. There are no patents in Prussia for Bessemer's invention. The result is, that the Prussian iron manufacturers are now rivalling yours. They carry on their operations at a great advantage as compared with British ironmasters. I am told that very large contracts for steel and iron rails, that used to come to this country, are now lost to this country; and that may be attributable to the large royalties exacted by Bessemer. These royalties run from between £1 and £3 per ton. How much *ad valorem* is that? It cannot be less than 10, and may even be 30 per cent. on the cost of the article. How can British manufacturers compete? When the principle of free trade was inaugurated, it was on the implied understanding that equity would prevail, that the British manufacturer would not be made liable to exceptional burdens. When we had differential duties, it was a matter of indifference, in competing with the Continent, whether there were patent burdens or not. But free

trade altered that. Now, when there is such keen competition, if the British manufacturer has to make heavy payments to holders of patents, it is impossible for him to compete. Certainly, he does not compete on equal terms. The British nation imposes upon him exceptional duties, which it does not impose on his rival competing from abroad. So clearly is this the case, that a friend of mine at Ghent, when this subject was introduced in the International Association for the Promotion of the Social Sciences, actually proposed that the British Customs should charge exceptional duties on articles from abroad, to counteract this. That was, of course, an impossibility. Mr. Cobden, a clear-headed, practical man, told me himself that he went thoroughly for the abolition of patents. Mr. Day will not have abolition, and he ridicules and repudiates State grants of money as a substitute. But it is quite possible to thus reward inventors. I have, in a book which I ventured to publish, exhibited a scheme which I think is worthy the attention of this Society. By that scheme, these two great objects might be simultaneously attained: liberal and equitable rewarding and recognition of inventors, and emancipation instantaneously of British manufacturers from the burden of paying royalties. I wish to clear the British, or rather the English, Parliament from misconception to which it may be exposed through statements made by the reader of the paper. I do not know what the history of patents for inventions in Scotland is. When we speak of the Statute of Monopolies, we speak of an Act of the English Parliament applying only to England. In that statute, there is not a word about vending of inventions, or vending of things made under patents. There is no prohibition whatever of that kind, just as in Prussia to this day. Suppose you make some article for domestic use by a new invention. You may import it into Prussia, and the holder of the patent for the invention there cannot interfere with your selling it. It was so in England, as I read the Statute of Monopolies. Goods might have been manufactured in Scotland, and sent into England, without the patentee being able to object. Not so, as the lawyers read the law now. I wish more particularly to call attention to words pronounced by the honourable gentleman very faintly. The words are these: that a patent shall only be granted, provided it is not hurtful to trade, that it does not raise the price of commodities, and that it is not generally inconvenient. I take the second first. I ask if there is any patent in existence but raises the price of commodities? Is it not a matter of experience that so soon as a patent expires, the article falls to a lower

price? Further, when the English Parliament agreed to tolerate that Act of Monopolies, only a limited number of persons—five, I think—were allowed to share in any patent. Now, by means of licenses, it is allowed not only to the patentee, but also to innumerable licensees. It was in order to prevent undue monopoly, that there was this limitation in the number of persons. One or two observations further in connection with the Statute of Monopolies. Patents were not to be "hurtful to trade, or generally inconvenient." All know that a patent is very hurtful to traders that do not get the benefit of it. I have already instanced a case in the iron trade. I could mention a case in the sugar refining trade, in which I was engaged till lately. I have it on the authority of a gentleman intimately acquainted with the parties. He gave it me in writing. In consequence of a monopoly being conceded to a house in Liverpool for a radius of seventy miles therefrom, to another house in Hull for a radius of seventy miles around it, a sugar refinery in Sheffield could not avail itself of improvements, and was ruined. Suppose the license granted. Patentees very commonly ask and expect for the use of their patents not a small share of profit, but, as I have known, four times what would be a living profit. (A voice, "It is not a fact. You are all wrong.") You can contradict me when I am done, when I hope you will be kind enough to answer me. The house with which I was connected, and which still exists, paid for a number of years a shilling per cwt. They might be content to work for a marginal profit of threepence per cwt. Is not that shilling four times what is a living profit? I have no desire to occupy much more of your time, except to clear the character of some of the labourers in this cause. We were told that no man of philosophical eminence had espoused the views of which I am a very humble supporter. I might allude to perhaps the greatest philosopher of the day, Monsieur Chevalier. Under his influence, we may soon have the patent system abolished in France. I might allude to a very eminent lawyer, a man of a very acute intellect, a man of excellent religious and moral principles, one who would not wrong an individual for the world—I mean Sir Roundell Palmer. I might allude to the Chairman of the recent Royal Commission upon Patents, Lord Stanley, the present Earl of Derby—to Sir William Armstrong, one of the greatest mechanists of the age—to Lord Granville, who was Chairman of the House of Lords Committee on Patents in 1851—to such great statesmen as Mr. Bright, Mr. Lowe, Mr. Cardwell, and Mr. Baxter. Without giving others,

I have shewn that if I have erred, I have erred in the noblest and weightiest of company. Before sitting down, I just ask two favours: *first*, that you will consider the alternative scheme I have ventured to propose as a substitute for patents; and *second*, that you will support Her Majesty's Government in the concession they have kindly made of leave to move next session of Parliament for a Parliamentary Committee to inquire into the policy of patents, and the best means of dealing with inventors. There can be no doubt that such an investigation as may be made by a Parliamentary Committee or Royal Commission will tend to establish men's minds, and to bring about a greater amount of harmony amongst us than now exists. I wish well to inventors; but as one who has been engaged largely in manufactures myself, I declare it is most unjust and most cruel to continue to expose the British manufacturer to exceptional burdens. I speak also for the great body of consumers; for their interests are one with the manufacturer's. I speak also for the great body of working men. No system can be more injurious for their interests than that which prevents cheapening of articles of consumption, and hinders the demand for labour. Patents diminish that demand. If they continue, they will withdraw to a considerable extent the manufactures of this country to countries where there are no such monopolies. One word more. We ought to negotiate internationally. There is no reason why each of the several countries of Europe and the United States should not pay a reasonable sum to every inventor. As we say, "Every little makes a meikle." It might not be much the inventor got from any single country; but if in thirty or forty countries in Europe and America, each gave a hundred or a thousand pounds, inventors would be more liberally treated, and be happier men than they are at this moment.

Mr. Walter Montgomery Neilson.—The only strong argument that the honourable Member has brought forward for the abolition of patents in this country, and certainly the only ground upon which a stand can be made, is the competition of Great Britain with foreign countries that have no patent rights. That is a great question of political economy, and is one which the honourable Member is certainly to be thanked for having taken up. As to the other statements which the honourable Member made, I am indeed very much surprised to hear them. The most extraordinary statement, as it seemed to me, was that patents do not reduce the cost of production.

Mr. Macfie.—I admit that inventions do so; but patents prevent inventions having that effect.

Mr. W. M. Neilson.—I differ from the honourable Member upon that point also. Perhaps this meeting, instead of going into general interests and principles, ought to have collected a number of facts upon which they might carry on a discussion. We, of course, cannot expect the Legislature to listen to us when we plead for the rights of inventors in the name of justice and truth. We ought to take up the broad fact, whether the patent laws of this country have induced men to devote their lives and their talents and their means for the benefit of their fellow-men. We have one or two examples. I shall limit myself to the iron trade, which perhaps I know more of than other trades. Reference has been made to the invention of the hot blast. That invention has reduced the cost of the production of the material enormously. At the first application of that patent, there was a saving upon the manufacture of iron of £1, 12*s.* 6*d.* per ton. The honourable Member stated that the patentees charged two or three times the amount of the saving which their patents produced.

Mr. Macfie.—I said that in a particular trade one shilling per cwt. had been paid, and that the manufacturers of the article who paid that shilling would be very thankful to carry on at a less profit than a shilling per cwt. If the patent is liable to that burden in this country and not abroad, it is very clear that manufacturers cannot get a shilling of a margin to pay the patentee. Suppose a sugar refiner is content with a profit of sixpence or threepence per cwt., how can he pay that shilling for the use of the patent right out of the sixpence or threepence, and also compete with non-patent countries?

Mr. W. M. Neilson.—The invention to which I alluded produced an economy of £1, 12*s.* 6*d.* per ton, and the charge made by the patentee was only a shilling per ton. I ask the honourable Member if there is anything extravagant in that small demand of a shilling per ton? I believe that the patent at this moment, and for many years, has saved the British nation something like £12,000,000 per annum. I may say also, that I know from personal facts, that had there been no patent laws in this country to protect, encourage, and remunerate inventors for their inventions, there would have been no hot blast. The inventor of that patent had neither the means nor the influence to carry out his invention. It has been complained also that inventors sell their inventions, and that the public have to pay patent rights to men who did not invent. In the case of the hot blast, the inventor sold it to two other parties, keeping himself a small share. Probably, it may be

said that the public had no right to pay them. Had this poor man not joined these two men, he never would have brought forward his invention. A complaint has been made against Mr. Bessemer for his charge for the process of making steel—one of the most wonderful inventions of the age, and one of the most useful, and that will before many years save many millions per annum to this country and to the world. The economy in the substitution of steel for iron alone is a matter of millions. I know myself that Mr. Bessemer at an early stage of his patent met with great difficulties; in fact, I think that man deserves a monument, not for his great invention so much as for his determined perseverance year after year. Failure after failure did he undergo, suffering greatly not only in means, but in health. But happily he persevered, and succeeded. Now, I ask, can this country or nation, or can any people, refuse to this inventor some reward for his great discoveries? Prussia, certainly, and other countries, have no patent rights. While the Legislature continues to protect patents at home, let it enact a law that for articles manufactured for exportation to non-patent countries, there should be no patent right. We must look to the British nation, and endeavour to place its manufacturers in a fair position as regards those of other nations. What have other countries done as compared with Great Britain? She has been a nation of inventors. Where have steam engines, steamers, locomotives, and railroads been invented? I hope the honourable Member will take these matters into consideration.

Mr. Macfie.—I wish to be allowed one word of explanation. I am extremely sorry if anything I have said should be conceived as expressed in a sense disparaging to Mr. Neilson or Mr. Bessemer. And with regard to Mr. Neilson, it was most honourable to him that he charged such moderate royalties, when he had the power to exact more. With regard to Mr. Bessemer, I know his high talents and merits. I adduced his case merely to state certain facts. Nothing in connection with his merits and talents will alter my statements. Before sitting down, I remark that the concession Mr. Neilson has made is all I ask for. Grant it, and my whole case is gained.

On the motion of the President, a vote of thanks was awarded to Mr. Macfie for attending the meeting, and taking part in the discussion.

Mr. James Robertson, Engineer.—With regard to some of the remarks of Mr. Macfie, he wished to state that personal vigour, such

as that possessed by Mr. Bessemer, was often a far more important element of success than the ingenuity manifested in the invention. One reason why such men ought to be rewarded is the determination and skill with which they endeavour to obtain success. Men like Arkwright and Bessemer would succeed in anything they took in hand.

It was then agreed to adjourn the discussion till the next ordinary meeting.

December 15, 1869.—The PRESIDENT read the following letter from Sir William Thomson, LL.D.:—

LARGS, AYRSHIRE, *December* 14, 1869.

DEAR DR. BRYCE,—I highly approve of the resolution regarding patents which has been moved by you, seconded by Dr. F. Thomson, and adopted by the Society. I have no apprehension that the abolition of patents, or of copyright, will ever be carried into effect, although it may be a good deal talked about. But I believe the discussion in our Society may be very useful in calling attention to the necessity for reform in the patent laws, and suggesting principles and details as to the alterations which ought to be made. I wish I could be present at the adjourned discussion to-morrow evening. But as I cannot, I write to suggest one important point which, so far as I can learn by the reports in the newspapers of your late discussion, has not been noticed by any who spoke. It is international and colonial patent laws. One of the worst features in the present system is the heterogeneousness of the patent laws within the British Empire and in the nations of Europe and the United States of America. I believe the patent law of the last-mentioned nation will be found to be in many respects better than our own. If, then, we can improve our own patent law by adopting some of the provisions of the American, it would surely be wise to do so, as we should thereby also prepare the way for an international patent law between the two countries. I hope the grand object of obtaining a common patent law among all civilized nations, which would give a great stimulus to useful invention, and do away with much of the confusion and inconvenience both to inventors and users of inventions, inseparable from the present anarchical condition of the patent laws of the different countries, will be kept in view by the committee of the Society appointed to consider the subject.—I remain, yours very truly,

WILLIAM THOMSON.

The PRESIDENT stated that, by order of the Council, the members of the Engineers' Association had been invited to be present. Such members of that Association as were present were entitled to speak upon the question which was to come before them. The PRESIDENT expressed the hope that the discussion would not have reference to private interests merely; but that, as the Philosophical Society of Glasgow, they would consider the question in a scientific and statesmanlike manner. Mr. Mayer, as having moved the adjournment of the discussion, was entitled to speak first.

MR. JOHN MAYER, after stating that he had no personal or professional interest in patents, and that he would consider the subject from the point of view of the public, said:—Mr. Macfie, who has now become the acknowledged leader in the crusade against patents, places great stress upon the fact that a few free traders and political economists have spoken or written against patent rights. Last evening he mentioned the late Mr. Cobden, Adam Smith, and some others. Even taking Mr. Cobden as a supporter of abolitionist views, I have yet to learn that, though his opinion on free trade in corn and other commodities is now embodied in our national policy, he was infallible on every other point in his political creed. Then, as to Adam Smith, I must confess that I am not aware of his great work, *The Wealth of Nations*, containing any objections to the policy of a patent law. Mr. Macfie, in the published report of his speech in the House of Commons, names amongst the defenders of patent laws Mr. M'Culloch, and asks, "What would Adam Smith think of his commentator?" Well, really, I don't know; but if he had had the opportunity, it would have been his duty to have complimented him upon taking a sensible view of the policy referred to. Amongst the opponents of the policy, Mr. Macfie quotes M. Chevalier and M. Wolowski, a French Professor of Political Economy, who is unsound on the banking question. Well, and what of them? Why, I think we might make him welcome to them, and to any half-dozen more of equal eminence besides, seeing that he gives us a man who as an exponent of political philosophy would be more than equal to them, though they were all rolled into one. I refer to Mr. John Stuart Mill, and I may inform the meeting that in his published speech, about ten pages are required by Mr. Macfie to controvert the patent law heresies of the greatest of our political economists. Mr. Macfie would have patent rights abolished, and would substitute *national rewards* for them, the value of the rewards varying

from £10,000 down to (what do you think?) certificates of merit! Who is to judge of the value of any new process that may be discovered, or new invention in mechanics, or engineering, that may be made? Mr. Macfie proposes an Invention Commission, and he says that in appointing the Commissioners, the Government should consult the various trading interests of the nation, in order to select the most acceptable persons. We may doubtless conclude that some eminent manufacturers would be put upon the Commission, and if so, the thing would defeat itself. Such a Commission would be as unstable as a house built of playing cards. If such men as Mr. Macfie, or other eminent *ex*-manufacturers, were to be chosen by the Government, what an inefficient set of appraisers they would make! How could they estimate the full value of a process, or a new appliance, or a *substantive* invention, until it had perhaps been years in operation? Why, look at this instance. Mr. Macfie, in his speech here at our former meeting, laid great stress upon the difficulties which the sugar manufacturer experiences with new processes. In his book he says:—"In that trade (the sugar trade), I myself, shortly before my retiring from commerce, paid £3,000 for a year's right to use a new process, which proved unworkable, and had to pay a *solatium* of £1,000 for leave to discontinue it." Now, if such an acute observer of men and things, and a person who was so "well up" in his own business as Mr. Macfie, should, in his desire to have the advantage of his fellow manufacturers, make such a great mistake as this admission shews, how could inventors be properly rewarded for their years of thought and labour, and their pecuniary expenditure,—amounting in some cases to £10,000 or £20,000, and in Mr. Bessemer's case to no less than £50,000, and six years' labour? The system of rewards is radically wrong. It would be quite unworkable. For, if the appraising and adjudication of the value of an invention or a process can fail so unmistakably in the hands of practical men, what would be the case if the Commissioners of Inventions were largely to be lawyers and such like persons, who knew nothing of things practical? Besides this unworkability of the system of rewards, it would doubtless give rise to all manner of jobbing, and the Commission would doubtless become, or be very liable to become, a great sink of iniquity, to which the Edmunds scandal is but as a drop in the bucket. Every Commissioner would be open to the influence of friends beseeching on behalf of inventors or persons who might think themselves entitled to that name. Great stress is laid upon the condition of things, in respect of patents, which

prevails in Switzerland, Holland, and Prussia. Everybody knows that the Swiss and the Dutch are not remarkable for their inventive faculty, and it is well known that Prussia steals the inventions which are perfected and brought into operation in this country. Now, that is just something like what America does in respect of the books of English authors; and the suggestion occurs to me that we might, through our Government, urge, with reference to Prussia and such States, the importance of an international patent right, treating, as is urged in respect of copyright, with American publishers. Between patent right and copyright there seems to me to be a close relationship; and that the former, although it is only granted for fourteen years, is as politic on the part of the nation as the latter, which is granted for forty-two years. If free trade, "run riot," is to abolish the former, it cannot consistently stop at the latter. If one goes, both must go. But there is no necessity for either going or being abolished. The patent laws are faulty. That is a fact upon which there is no difference of opinion, either amongst inventors or manufacturers. Let us, then, rather seek to improve and use them, than to improve them off the pages of the statute-book. That the present system of granting patents is attended with anomalies and abuses is no valid reason for doing away with the system altogether. We, the public, feel that by patented processes and inventions we are every now and then having our ordinary wants ministered unto more cheaply, and luxuries provided for us which we never dreamt of enjoying; and we would ask if those results have been attained at the expense of stifling the faculty of invention in any one? If our opponents will bring forward one *boná fide* case of scientific or manufacturing progress being hindered by patents, we will bring hundreds—I suppose I might say thousands—in support of the opposite view. A few selfish manufacturers may suffer now and then, or may persuade themselves into the belief that they do suffer, from the granting of patents in respect of operations in which they themselves are engaged; but that is no proof that patent right policy is not a good policy for trade and manufacture, and for the nation at large.

The President said,—By the invitation of one of the members, and by the authority of the Council, a distinguished stranger was with them to-night. He was sure that they would in the discussion grant precedence to that gentleman. He alluded to Mr. Samuel Cunliffe Lister, of Bradford, whose name must be known to most of the gentlemen present, as one of the largest patentees in the

empire—a gentleman who had expended upon patents money approaching to half-a-million, and who was now deriving great profits from the patents which he had obtained. He would call upon Mr. Lister to address the meeting.

Mr. S. C. Lister said,—By the kind permission of your chairman, I have great pleasure in taking part in the discussion to-night, more so because I feel that I am addressing a body of gentlemen who, by their scientific attainments, and by their practical knowledge of arts and manufactures, are perfectly qualified to come to a true, just, and unbiassed decision on the question now before us. I stand forward an honest advocate of the patent laws. My life has been spent altogether in connection with the subject. It is not my intention to-night to enter into an abstract discussion upon the rights of patentees, or upon the history of patents, but rather to lay before you, in as concise a manner as possible, my experience during a long period of years. After all, the question that is now before us is a question of practical results. I quite agree with what has been said by the *Times*, and by almost all the papers—namely, that if the patent laws must be maintained, it must be by proof that they do render essential benefits, not to inventors alone, but to the nation at large. It is upon that ground, and that alone, that I desire to discuss this question.—After the debate in the House of Commons he wrote two letters, which were published in the local paper of the district to which he belonged. He would read them, inasmuch as one of them was intended to be a reply to the arguments used by Mr. Macfie, Sir Roundell Palmer, and Lord Stanley; and the other was a short history of one of the first inventions in which he was engaged. The first of these letters concluded as follows:—

"Without the law we should not have one inventor where we have a hundred now, for the best of reasons, because it would not pay. During the last twenty-four years I have taken out sixty-four patents, and have spent between three and four hundred thousand pounds in carrying them into practical use. I have fought eight or nine actions at law; I have given to other inventors above one hundred thousand pounds, and, together with my co-patentees (especially Mr. Donisthorpe), I have saved the trade of Bradford millions; and, notwithstanding all this expense and trouble, I have —what is of no little importance to myself, although, perhaps, of none to the public—won a good stake, without the hope of which inventors and inventions would soon cease."

The second letter sketched the history of his machine for combing

wool. In the course of reading these letters, Mr. Lister interpolated remarks to the following effect:—That, having worked hard in connection with inventions, he had a right to the protection of the law, and that it would be very hard if, after having achieved success, that success were seized upon by competitors who had done nothing to obtain it. A man who had worked a process before a patent was obtained for it, had a right to continue to work it afterwards. With respect to the wool-combing machine referred to in his letter, he said that it had made a marvellous change in Bradford; in fact, it had changed the whole nature of the business. All parties had endeavoured to overcome the difficulties in the combing of wool, and of course the first machine was invented by Dr. Arkwright of Doncaster, to whom Parliament granted £10,000 of reward for his invention. However, it was a good invention for him alone, for it never combed a pound of wool; and if we were to have a system of State rewards, we ought to have something for our money. Without a patent law, how many would not move a finger? and he appealed to them, as a sensible body of men, whether it was reasonable that a man who had risked his fortune, and spent many years of his life, should have the fruits of his toil taken from him by competitors? It had often been suggested that we should have a committee or body of experts to examine inventions before patents are granted. Now, if a jury and a judge, having all the aid of scientific witnesses, could not discover any difference between the two machines, yet the trade—the one patent expiring before the other—Heilman's expiring four or five years before his (Mr. Lister's)—gave him £1,000 of patent right. The machine cost only £150, yet the jury found there was no difference between the two machines. I cannot (Mr. Lister continued) give you a stronger illustration of the impossibility of any body of men examining and reporting upon the merits of inventions. Even take me in my own department—wool-combing, in which I am thoroughly versant—I feel I should not be able to decide upon the merits of inventions in all cases. I might be able to decide in a majority of them; but I should frequently do injustice; therefore, I consider it is utterly impossible for any body of men to do this work. Possibly, a committee might cast aside a number of trifling things, and weed out a lot of chaff; but they must lavish money with a liberal hand, else they will do great injustice to inventors. I was fought tremendously by machines in operation; but at the present time, I will be bound to say that the whole trade with one acclamation will say that no man has ever

done them more good than I have done. Yet Sir Alexander Cockburn called me the great monopolist. However, I shall not trouble you with any more personal matters than I can possibly avoid. But still I will be obliged somewhat to refer to what I have in hand, because my object is this: you can find numbers of men who can write you able treatises upon the patent laws for and against; but you cannot always get hold of men who have spent their lives in carrying out inventions of importance, and of national consequence. It is from that point of view that I wish to speak upon the patent laws. The next matter after the wool-combing I took in hand was brought to my notice somewhat singularly. I was in town in the year 1844 or 1845. A silk broker called my attention to a piece of dirty stuff which he called chassum. He said he would take a halfpenny per pound, and that there were hundreds of bales. I bought them. I set to work to try to make some use of it. He said any quantity could be imported, if I could use it. I worked for ten years. I was out of bed early and late; up at half-past five o'clock, and at work till a late hour. I spent, or rather I advanced, £360,000 before I accomplished the end sought. At last I mastered the difficulty. What are the results? I did not injure trade; but I created a new trade. Chassum was unknown. Chassum was not used in trade at all. We now import 3,000 bales ourselves, besides using largely the importations of others. What is the price? From 1*s*. to 3*s*. 3*d*. I wish to shew that, in this special case at any rate, I cannot be said to be injuring the public—there is so much said about patents damaging the public. Here a new manufacture was entirely created, which did not exist. But suppose the patent law had offered me no protection, can you suppose that I should have madly gone on, after seeing my fortune vanish, to obtain that which, the moment I had accomplished it, competitors were at liberty to seize? Having accomplished that, I took in hand a new race—a race in which all can yet enter, because I have not accomplished the results sought. It is a race the conditions of which are immense labour, large expenditure, and possibly no result. Mr. Macfie is quite at liberty to enter the race, if he thinks fit, or any of you gentlemen. I can tell you I am going to offer you splendid stakes—one of the best cups of the day. I will offer you £50,000 if you manage it. What do you think it is? It is a manufacture which at the present time does not exist in England—at least, only in a very subordinate state—the manufacture of velvet by power. It is called black velvet. That velvet at the present time is manufactured altogether at Crefeld or Lyons, and

different parts of France. We supply the larger portion of the yarns for its manufacture at Crefeld. But as I have said, there is no manufacture of that kind in all England. Now, it will be a source of great pride and pleasure to me, if I can create a new industry without injuring my neighbours—if I can bring to England that which enriches her without damaging my neighbours. I have said I have taken in hand a new race which is open to you all. But I tell you, none of you will accomplish it without years of labour, and thousands of expenditure. But it may be and it will be accomplished by perseverance, knowledge, and application; —especially, and above all, by hard work.

After dwelling upon the injustice of depriving an inventor of the reward of his labour, anxiety, and expenditure—an injustice which could only be equalled by stripping the landlord of his broad acres—Mr. Lister proceeded:—

Then let us look at the question in another point of view. Mr. Macfie says, "Oh, Mr. Lister, we have got a scale of Government rewards; let us see in which category we shall put you. Shall it be in the £10,000, the £50, or the ticket of merit?" I see, upon looking at the long list—for I have nearly forgot all my labours—which enumerates something more than sixty-four patents, my maiden effort was for applying fringes to shawls. That was successful. We fringed thousands of shawls with the machine. The cost of it was £100. Well, in a case like that, it would have been a nice maiden reward to have got £10,000. I would have thought I was an uncommonly clever fellow, and would have prized such a reward highly. Well, in such a case, the Government reward would answer. But let us think what is to be the measure of reward of a man who stakes his all—not that I intended to stake it, but I was led on, as many are often to their ruin. I find, in looking at the balance sheet after we had achieved success, that we wrote off—although I advanced £360,000, that was not all lost, mind you—we wrote off in the next balance sheet, when we began to make profits, a quarter of a million as absolutely gone. But suppose, on Mr. Macfie's system, we had gone to Parliament, Mr. Macfie might have said, "Good fellow, Mr. Lister, you are very ingenious. We will treat you liberally; we will take you to the House, and see what is to be done." "The first thing that I want," I reply, "is the money of which I am out of pocket. Please to hand me £250,000. Then, Mr. Macfie, I'll tell you what I want. Any man who runs the risk of losing £250,000 is entitled to at least double the amount

he has spent, and I will thank you further for £500,000!" Mr. Macfie goes to the House, and he says, "Well, gentlemen, I don't think it is an excessive reward." I suppose he says so. I suppose he means to treat me well. What does the Chancellor of the Exchequer say? "£750,000! where is that to be got?" The thing is absurd. I only give you an illustration of how foolish and nonsensical such a thing would be. And further, the system of State rewards will certainly end in money being given for a multitude of things which look on the face of them as if they were practical things, but which will prove not to be so. A man will shew a loom which works well so long as he sits by it; but when it passes into the ordinary workshop, and comes into practical hands, it is not worth having. And yet the man receives £10,000, as if he had done a very clever thing! Well, to turn to my last baby, the loom for weaving velvet. Suppose there were no patent law; suppose it were abolished to-morrow; what would I do next day? Shut up shop; and in so doing I should only be acting as everybody else would. But there are lots of people, says Mr. Macfie, who like to work for the public good; lots of rich men who, from love of their country, will spend their money in this way. I confess I have not sufficient public spirit to do so; and I think the majority of us would say the same. I have an illustration also pointing to the fact that the Patent Office is of great use in recording the exact state of any new process of manufacture. As a matter of course, all sorts of inventions, including the least valuable, flow to the Patent Office; and any man who wants himself thoroughly posted up, goes to see what his competitors are doing. Without the record of the Patent Office, lots of us would be travelling over the same ground; and I cannot give you a stronger illustration than what happened to myself some time ago. I invented a swivel shuttle of peculiar construction for inserting silk into a plain ground. Well, though that invention was made twenty years ago, a gentleman called upon me the other day with a new patent shuttle, being precisely the thing I invented twenty years ago! Because I had not patented it, he travels over precisely the same ground. This shews that the Patent Office is very valuable in that point of view. I have only cursorily looked into this book, *Abolition of Patents*, but I have seen enough to cause grave thought. I readily admit that there may be a good deal said on the other side of the question, because I know very well that you may put the thing in various lights by which the public are injured; but I think I have already shewn to you

that if there be evils, there are greater counter-balancing advantages, and that to destroy the patent law would be tantamount to destroying the inventive genius of the age. Now, Mr. Macfie, though he has some very weighty reasons, has a great deal of chaff with a very little corn. Amongst other things, he endeavours to make it out that inventions raise the price of products, and quotes the case of Mr. Bessemer's patent, on which Mr. Bessemer charges £2 per ton; and he says, if that £2 per ton were not charged the iron would be sold cheaper, and he calls that raising the price. Everybody knows that a patent is entirely useless unless it makes something better or cheaper, because it must necessarily come into competition with the thing that exists; and it only can be successful either by reason of its cheapness, or its bettering the thing which it competes with. In Bessemer's case a better thing is produced; and Mr. Macfie is entirely at sea in saying that patents enhance the price of materials. A gentleman has published a short essay on patent right—a gentleman in Glasgow of some celebrity—and it is an exceedingly clever article, but I think he is practically unacquainted with the subject he writes about. The writer is Mr. James Stirling,—a man who has, I am informed, written some clever works; and that is the very reason why I have selected him, to analyze what he has to say as an authority. He says, first, "Patent right cannot be defended on the ground of justice." I say it can. I say my patents for my silk process, my wool process, and velvet process, are all patents of justice, and patents which I feel every one will admit I am thoroughly entitled to. The next thing he says is, "The object of a patent law is to establish a 'property in ideas.'" If I know patent law at all, I should really be puzzled how to make a valid patent out of an idea. I would have great difficulty in finding an agent who would make a patent out of nothing. That argument is based on a false ground. Then he says, "Thought cannot be appropriated." Certainly, ideas cannot be appropriated; neither can patents be taken for ideas. He thinks they can. Again, he says, "Patent law is founded on a conventional, not a natural right." I appeal to you whether my experience does not shew that it is founded, not on a conventional, but on a natural right,—the natural right that a man has to enjoy the fruit of his own labour. He finishes by saying, "On the whole, patent law seems a blunder, founded on the antiquated notion of giving State encouragement to certain favoured modes of human activity." Altogether, Mr. Stirling's essay shews it to have been written by a man who

is not practically acquainted with the working of the law, and I may pass it over without further notice. All I have to say in conclusion is, that I feel that to abolish the patent law would be neither more nor less than to cut off the right arm and pluck out the right eye of commerce and ingenuity, and thus maimed, to leave us to struggle as we best could with the competition of the Continent.

MR. EDMUND HUNT.—To consider whether or not there should be a total abolition of patents seems to me almost like wasting the time of the Society, for I am sure that if the votes were at once taken on that point, they would shew a very large majority against abolition. I think the resolution which has been proposed should have been more strongly worded in reference to this point, and that it should have been divided into two or more separate resolutions. I would have the first resolution in the form of a simple negative to that recently proposed in Parliament by Mr. Macfie. I would say,—"In the opinion of this Society the time has not arrived when the progress of the arts and manufactures in this country would be promoted by the abolition of patents for inventions."

Abolitionists deny that, as a rule, inventions and discoveries would be kept secret if there was not the inducement of patents to promote their publication; but what can they say to the positive fact, that even our present patent system does not hold out sufficient inducement to cause the publication of such inventions as can be conveniently worked in secret. It is well known that at this very moment several lucrative inventions are worked in secret, and, of course, without patents, which involve publication. I may instance an early invention of Mr. Bessemer, the prolific inventor, who has already been frequently utilized as an illustrious example in the present discussion. That invention was for making bronze powders; it was never patented; but has been very profitably worked in secret for a period equal to the duration of two or three successive patents. Some of the best processes for making colours from coal-tar are not patented, but worked in secret; and, no doubt, many members of this Society will be aware of various valuable chemical processes which are worked in secret in this neighbourhood.

The existing patent system has various defects which are generally acknowledged, but remedies have been proposed which, if not attaining absolute perfection, are so certain to be very beneficial, that even abolitionists cannot refuse a trial of them prior to the carrying out of their extreme views. We must remember that the present system has practically shewn itself to be a very great improvement

upon that which existed prior to its introduction in 1852; but after seventeen years' experience of it, it is quite time to look out for something better still.

An important question is the cost of patents and the taxes on them. I agree with those who say, the taxes paid on first obtaining a patent should be not more than what will cover the expenses of the Government Patent Office,—I mean the expenses of a simplified system, and not those of the present one, for they are most unnecessarily increased by, amongst other things, the splitting up of the process of obtaining a patent into three or four formal stages, when one or two at most would be quite sufficient. If, however, our legislators decide that patents shall contribute to the revenue of the country, then, I say, it is not just that they should do so, except out of realized profits; nor is it just that every patent should contribute alike,—one yielding, say, £10,000 a year, paying no more than one yielding £100 a year. If, then, patents are to contribute revenue, it should, in my opinion, be in the form of an extra income tax on profits, which could be collected as easily as the ordinary income tax, and along therewith; which would bear more fairly on patents of different values, and which would not be grudged by patentees, like the present patent taxes.

The patent system in the United States is superior to ours, and I, for one, would accept its introduction here in an unaltered state as a great improvement. At the same time, I think we can do better—we can adopt the good features of the American system in a modified and improved form. We must, certainly, adopt the plan of examining into the novelty of inventions proposed to be patented; for the most outcrying evil of our system is the repeated patenting of the same things. There is something almost of the nature of fraud in the working of our system. A person sincerely believing himself to have invented something which turns out to have been previously patented, pays the Government for a patent—that is, a document professing to vest in him certain valuable rights—whilst there exists in the same office the means of knowing that the self-same commodity has already been sold by Government to another person. The Government, in fact, sells and receives payment for something which it has not to sell, and cannot deliver.

Now, there must be no mistake about the examination as to novelty being properly effected under any new Act. The Act itself must be clear and definite on the point, and must contain arrangements and regulations for carrying it out, so that it will not be left in the power of Commissioners to nullify its benefits by unsuitable

regulations. I am very sorry to see a very great deficiency, in this respect, in an Act that has been proposed by the Council of the Inventors' Institute. The proposal embodied in this Act is, that there shall be six assistant Commissioners, and it is just mentioned that they are to institute an investigation as to novelty in the case of each invention; but no mention is made of assistant examiners, nor of the various arrangements absolutely requisite for securing a thorough examination. Any one conversant with the subject will, I am sure, agree with me that six examiners are not nearly sufficient.

In the United States, the examiners have the power of refusing a patent for a thing which they imagine not to be new. I say *imagine*, because in practice the question of novelty generally involves points as to which personal opinions may differ very much. There may be cases in which there is complete identity between a thing proposed to be patented, and another thing patented previously; but such cases are very few. There are, however, a great number of cases where there is very great apparent similarity without complete identity,—and such cases are likely to become more numerous each year; for, as improvements multiply, they have necessarily to deal with smaller details, and individually constitute smaller apparent advances, whilst, in the aggregate at least, they are not by any means less useful and valuable. What really gives rise to the outcry about re-patenting, is the common fact that a patentee—not knowing of the existence of something similar to, but not identical with, his own invention—draws his claim, so as not only to include his precise arrangement, but also similar things. This is done, naturally enough, with the intention of warding off such competition as would diminish the value of his patent; and in this way many claims are drawn too wide, and so, taking in things which turn out to be old, render the patents invalid. This would obviously be remedied by simply communicating the necessary information to the intending patentee. Without being aware of it, probably, the American examiners sometimes exercise functions which their laws do not give them. They will say, for example, that a certain improvement is not patentable; the reason they give being generally that it is too much like something previously known and in use. I know of cases wherein this has happened, and the particular improvements have afterwards turned out to be of great value, and the patentability never questioned by practical men. Of course, the American law provides for appealing against the decisions of the examiners; and in some of the cases I have referred to, patents have

been ultimately obtained. But this appealing involves very much extra trouble and expense, and is, in my opinion, altogether uncalled for. I object strongly to any arbitrary decisions by officials affecting the interests of intending patentees. I think the expression of opinion by officials is uncalled for. If a system of patents is a good thing, as I believe it to be, its object, from a legislative point of view, can be none other than to encourage inventions, and through them to promote the general progress and advancement of arts and manufactures. Consistently with this view, the inventor should be assisted in every way; and I would claim the examination as to novelty as a boon to inventors, and as an assistance to them; and I would earnestly deprecate the contriving of this examination so as to make it a terrible ordeal that an inventor has to go through, like that which a student has to pass to obtain a diploma or degree.

When an inventor lodges a description of an invention which he wishes to patent, the examiners should make a report upon it, involving the question of novelty, but not confined to that question. The report should be in the form of a simple statement of things previously patented, or otherwise accessible to the examiner in public works; and not only of any that the examiner may happen to think exactly or almost the same as the invention in question, but also of any bearing an obvious resemblance or relation to it. It is only in this way that the examiner's labour can really be fully utilized; for even if his report were merely, "It is new," or "It is not new," he must have referred to and compared all those things that he would have to mention in his fuller report. And there is yet another reason for the fuller report: the inventor ought clearly to learn as much from the report as he would have learned by making the search and examination himself. Indeed, in my opinion, the true and incontrovertible argument for an official examination as to novelty, is that of the economy of labour it involves. At present, even, an inventor can avoid re-patenting an old thing by making a thorough search through the public records of things previously patented or in use; but if every inventor were to do this, it would involve an immense amount of repeated labours, the same ground being gone over by one after another incessantly. With an official board of examiners, each member of it will confine himself to one subject, with which he will rapidly become thoroughly familiar, and the examinations will in consequence be effected with infinitely less labour, whilst the examiner's disinterestedness will render the *results* more accurate and reliable.

The inventor should receive a copy of the examiner's report as soon as possible, and it should be at his option to demand a patent or not as he sees fit, or to submit an amended specification or description. The reports must also be accessible to the public in some form or other; otherwise, it would be possible for fraudulent persons to obtain patents for old things and mislead the public; but there may be a diversity of opinion as to the best manner of making the reports accessible. My own opinion is, that the specifications should be published as at present, and the reports printed in full along with them. The specifications might, however, be printed separately, and copies of the reports be obtainable at the Government office only when specially asked for; and in this case, the specifications might have short abstracts of the reports, or perhaps nothing at all. I think, however, that if the ordinary specification prints contain either no reports, or short abstracts, or even if they contain official expressions of opinion—as some will probably maintain they should—any interested person requiring to see the specifications at all, is sure to desire to also see the full reports, and therefore the simplest and most complete plan will be to print them along with the specifications.

There is one valuable feature of the American system, the adoption of which is most desirable and important. In our own country, the law will not allow an inventor to in any way publish or publicly try his invention before he applies for a patent,—a patent being invalidated by prior publication, even by the inventor himself. I have never heard an attempt even at an argument, in support of this; and I think it is the principal cause of patents being taken for frivolous things, and untried schemes. It is also the cause of many valuable improvements being practically lost to the country. I refer to cases that are more numerous than may be generally supposed; wherein improvements are put into public operation without a patent being thought of until too late. An inventor in such a case will often afterwards inquire if he can get a patent, but finding he cannot, has no interest to induce him to push the introduction of the improvement, and the public lose the benefit of it. In America, an inventor can get a valid patent so long as his invention has not been in public use more than two years; he has, in fact, what is practically equivalent to a patent for two years without either cost or trouble. I have never heard a hint of the least disadvantage in any way arising from this provision in America.

It is even worth considering whether the law should not go a step further than to merely *allow* of improvements being tried, and insist

on their being tried before a patent can be obtained. At any rate, a patentee, or assignee of a patent, should not be entitled to proceed against alleged infringers until he has got his invention put into practice, either himself or by others for him.

In conclusion, I would draw attention to the motion Mr. Macfie is to bring forward in Parliament during the ensuing session. He tells us it is for a committee to inquire into the present State method of dealing with inventions. Now, this is so worded as to include the question of abolition, and in this form it cannot be supported by this Society, if the first resolution is agreed to, either in the form proposed by our President or in that suggested by me. But I think there can be no doubt that Parliament will have some inquiry made before passing any new Patent Act, and I think any resolution of the Society on this point should be so worded as to urge the carrying out of the inquiry in the most comprehensive and complete manner. Such an inquiry as was instituted in 1862 would be simply ridiculous. The Commissioners must not confine their labours to London, and to the reporting of the remarks of any one choosing to present himself before them. If they are to collect any reliable information, they must search it out in the various great centres of the arts and manufactures, and they must ascertain who are the persons whose information and experience are worth reporting, and call upon them to communicate them. They must learn what the working man himself has to say on the matter; and not be content, as in 1862, with lawyers' and employers' opinions as to how the working man has been affected by the patent laws, or will be affected by proposed alterations. I would suggest the following for the second and third resolutions:—

"The seventeen years' experience of the Patent Law Amendment Act of 1852, whilst proving that it possesses important advantages as compared with the system previously existing, has shewn that various great but remediable defects are associated with it, and the time has arrived for the introduction of an improved system of patents avoiding those defects."

"Any Parliamentary inquiry, instituted with a view to improved legislation, should be conducted so as to collect the fullest possible information from the various important manufacturing centres of the kingdom, and from all classes in any way concerned in inventions or patents."

Mr. Andrew Barclay, Kilmarnock.—Having taken out a good many patents, and spent upwards of £20,000 in making experiments, *my* opinion is, that it would be a great loss to the community at large

if any attempt were made to entirely abolish the patent laws. In 1864 I took out a patent for an improvement on the jacquard, by which that great instrument is made to act as an ejector as well as injector; to throw out, as well as to throw in. I spent from £6,000 to £8,000 in improving that instrument; and having got it well nigh perfection, and obtained a patent for it, it would be a very great hardship if the public were now to reap the benefit of my five or six years' labour, at an expense of not less than £6,000, toiling from early in the morning till two and three next morning, when it had failed to perform its functions as I expected, till I succeeded in obtaining the results I desired. I may state that the first of my inventions was one in 1842, by which gas lustres were suspended without the use of weights, by the adoption of the beautiful fusee of the watch to regulate the descent. I sold that to Messrs. R. Laidlaw & Son for £100. The last time I was in their office they told me they had made 33,000 of them. I averaged they would have £1 off each of them, and thus they have made £33,000 off my £100!

The President then moved a vote of thanks to Mr. Lister, for his having come from England to address the meeting,—which was carried by acclamation.

December 22, 1869.—The Society held a special meeting to continue and terminate the discussion on the patent laws. The discussion was resumed by—

Mr. J. G. Lawrie.—There can be no one who denies that those who discover a great invention, which is useful to the country, are unquestionably, in common with all public benefactors, entitled to public rewards, and that, if the patent laws accomplish the end of bestowing such rewards satisfactorily, they should be supported.

The invention of the condensation of steam in a separate condenser, which was the great invention of James Watt—the application of heat to the air with which smelting furnaces are supplied, which is the great invention of the hot blast—the application of the screw propeller to the propulsion of steam ships, an invention which is second to none in connection with steam navigation—the electric telegraph, which will one day monopolize all the important commercial intercommunication of the world—are inventions of vast importance, and upon the authors of such inventions should be ungrudgingly bestowed liberal rewards.

The theory of the patent laws undoubtedly is, to reward great

public benefactors—such benefactors as the authors of the inventions I have named. The theory is, that each invention is a clear, well-defined, and separate discovery; that it stands apart from every other; that it is the production of the inventor who obtains the patent; that it is of great national importance; and that the invention would have remained unknown for a considerable time at all events, but for the efforts on account of which the patent has been granted.

The fact, however, is, that probably no invention ever made—certainly none of those I have named—was wholly invented at one step, or by the efforts of one author or of one patentee.

All inventions, or certainly all of importance, have been the result of gradual successive steps, of which the last has been but the copestone, or the link fitting and connecting the whole for application. In many cases the earlier steps, which received no reward, have possessed the greater ingenuity, have been the result of the greater amount of labour, have been the largest strides in advance, and have certainly been entitled to the largest rewards.

For example, the locomotive engine, which is one of the most useful as well as one of the most ingenious machines ever contrived, has been the result of a thousand successful and successive steps, each contributing materially to the pitch of excellence to which it has now reached. The link motion—a most important part of this engine, and one of the most simple not less than one of the most elegant mechanisms in existence—has advanced through many ingenious steps, and now that the main or principal action of this mechanism is perfected, it is impossible to award the share of merit deserved, with any accuracy or fairness, to the different contributors.

The burning of smoke, and the use of coal in locomotives—another most important element of this machine—has also advanced through many steps, and been the subject of many patents. Chemical principles defined the conditions by which this advantage could be obtained, and mechanical contrivances were combined to fulfil these conditions. These mechanical contrivances were the subject of numerous patents; yet it is abundantly obvious that without a knowledge of the chemical principles the mechanical contrivances would not have been proposed, the end sought could not have been attained, and it is therefore not difficult to decide that the chemical discoverers of the conditions to be fulfilled, who could not have obtained a patent, and who did not receive any reward, had greater claims to be the true discoverers of the process than any of the numerous mechanical contrivers, of whom all who chose were *rewarded* by the protection of a patent.

The locomotive engine being comparatively a recently contrived machine, its history is not forgot or obscured by time, and, being wholly a new machine, its construction has been developed rapidly, yet it is utterly impossible even now, when the facts are vivid and distinct, to divide the merit belonging to any one part of it among those who have contributed to its advance, or to award with justice patent rights to one, to the exclusion or in preference to the others.

If the locomotive engine had been a single invention, the production of a single inventor, or if a considerable part of it had been so, then, in the spirit of the patent laws, a public reward might have been justly due, and then the dangers of litigation among contending and rival inventors might not have been incurred; but the fact is, that almost each pin, and certainly each detail of the contrivance, has been contributed by so many different inventors, leaving scarcely a point of detail, in the words of Robert Stephenson, which is not a subject of dispute, that nothing can be more unjust than to award to one or more of these inventors a preference, to the injury of the others, while, in reality, none of them have done anything more than would have been done by an equal number of other engineers who might have happened to be employed upon the work in which the locomotive originated.

Such are the facts concerning this machine, and concerning the patents which abound around it, and such are the facts, to a greater or less degree, regarding every other invention, whether the object be important or unimportant. In the words of a writer of some distinction,—"Among the number of patents granted, there are comparatively few which can be called original, so that it is difficult to say where the boundary of one ends, and where that of another begins; that which is hailed as an original invention is often found to be but the result of a long succession of trials and experiments gradually following each other, and ought rather to be considered as a continuous series of achievements of the human mind, than as the conquest of any single individual. One starts the idea, another develops it, and so on progressively, until at last it is elaborated and worked out in practice; but the first not less than the last is entitled to his share in the merit of the invention, were it only possible to measure and apportion it." To give State distinction, State protection, and State reward to the last alone, is not more unjust to the others and to the public than it would be to award to the proprietor of land, who happened to be the last arranged with of a hundred through whose lands a projected railway is to pass, a payment for the land proportioned, irrespective of its intrinsic value,

to the necessity of procuring the land of that proprietor, it being then the connecting link of all the other land already arranged for, and which, without this connecting link, would be almost worthless for the formation of the railway. Plainly, such a value would be most unjust. Patents are so readily obtained for every kind of claimed invention, whether it be really new or really old, whether it possess any utility or be of no value whatever, that those inventors, who are far from being well informed on the subject which they seek to improve, are not unfrequently most prolific in supposed inventions, and most prolific in patents. On this account patents abound which are utterly worthless in their object, and utterly worthless from want of novelty.

These defects not unfrequently recoil upon the patentees themselves, who are, in consequence, involved in considerable expenditure and great disappointment. Thus, although the theory and the intention of the patent laws is to protect and to reward meritorious inventions and meritorious inventors, the practice, the abuse of the intention of the patent laws is, that inventions the most worthless receive the distinction of protection, and inventors, who have no just claim whatever to reward, are armed with an instrument by which to demand it from the public.

By abuse of the intention of the patent laws, inventors are armed with the means of demanding from the public a payment or, in many cases, virtually black-mail for patent rights which should not have been granted. Inventors are armed with the means of involving the public in litigation to defeat unjust demands, or of enforcing from the public compliance with these unjust demands, under terror of litigation. Inventors are armed with the means of fraudulently assuming the name "patent," and thereby imposing upon the public. Inventors are armed with the means of fraudulently imposing upon the public by the sale of articles at high prices, calling them patent after the patent has expired. And inventors are armed with the means of involving themselves in great disappointment and in great loss, under the allurements of what is little else at best than a lottery for profit, but which more frequently proves to be a snare and a delusion.

These are effects arising from the patent laws, each of which is productive constantly of a vast amount of injury.

To remedy these defects in the operation of these laws, it has been proposed to sift the applications for patents before the patents are granted. It has been proposed to appoint a standing Commission, or to establish judges, before whom all applications for patents

would fall to be supported, and who would decide upon the merits of the applications, whether they be new, and whether they be of utility sufficient to justify the bestowal of a monopoly. But no judges or Commissioners, however well informed, or however numerous, could possibly perform these duties. In the administration of the law concerning common property, the rights of parties cannot be ascertained without the examination of elaborate evidence produced by opposing interests, and these rights constantly turn, even under such searching investigation, upon niceties that perplex judges, counsel, and jury. If these difficulties occur with the claims of ordinary property, they would occur much more frequently, as they do at present, in patent cases, under the technical questions which would arise in the applications for patents for inventions—questions that would, in most applications, if not in all, be unexplained by the full evidence which is now produced in patent cases, and that, being unexplained by practical application, no human foresight could enable any judges to look into futurity and to give effect to the ever-varying circumstances that turn up from time to time, under which the value or the importance of an invention increases or diminishes. Moreover, even with the fullest investigation that can be made, experience tells us that it will not do to accept the condemnation of any discovery upon the ground of an unfavourable opinion entertained by compeers, seeing that some of the greatest discoveries recorded in history were condemned as erroneous and worthless, by contemporary judges; and for the same reason it would not do to accept the importance of a discovery upon such grounds.

Such a mode as this, by a Commission, of disposing of the applications for patents, if carried out with any attempt at efficiency, would incur very large expenditure, and could not be otherwise than extremely unsatisfactory in results.

Patents, if granted at all, must either be granted freely, as at present, or under restriction, as proposed, by examination before they are granted. No feasible third course has been proposed or is apparent; and as the first of these modes is most unsatisfactory, and the second is wholly unworkable, the question arises, Whether, apart altogether from the rights of the public involved in the principles of political and international economy, which are outside of the scope of these remarks, the granting of patents should not be discontinued, and whether they can be discontinued without injustice to inventors?

Patents are granted to inventors for discoveries that are in-

genious and of public utility; and if they be granted to some discoveries because of these qualifications, it is impossible, it appears to me, to see any just grounds upon which they can be refused to all and every discovery that does possess these qualifications.

It is not alleged, and it cannot be alleged, that the expenditure incurred by inventors in experiments is a good ground for saddling the public with a monopoly. An inventor, in all necessary expenditure, incurs no greater risk of loss than is inherent to all mercantile enterprise. A merchant exhausts every source of information, and upon the information he receives he regulates his operations, which are profitable or unprofitable as the event may prove. A shipbuilder undertakes to build ships; the men strike, and imperil the whole transaction. And betwixt the expenditure of an inventor, and that of a merchant or shipbuilder in the hope of profit, there is this remarkable difference, that all the unsuccessful and unnecessary expenditure of an inventor arises from blunders of his own, and is wholly attributable to his own want of attainable knowledge in the principles with which he is dealing, while the losses of a merchant or manufacturer most frequently occur from the effects of a changing market—a cause wholly beyond his control, and in its very nature beyond all human intelligence.

The £360,000 which our friend Mr. Lister tells us he spent in experimenting for the improvement of his patents, proves his extreme unacquaintance at that time with the subjects he was handling. These inventions had not at that time been advanced to a state without which no inventor should, in fairness, feel himself justified in even asking a monopoly that will destroy the progress of improvement by every one else in the same direction. If they had been, no such expenditure would have been necessary, nor would so much labour have been required for the sixty-four patents, upon each of which he paradoxically tells us he worked for substantially a lifetime, from half-past five in the morning till late at night. £360,000! A man who owns that sum, and experiments it all away, is indeed a great and rare genius. "Rara avis in terris, nigroque simillima cygno." No other specimen of this singular species has, so far as known, ever appeared north of the Tweed. £360,000! It is impossible to help wondering whether that figure included compound interest, and what the rate might be. £360,000!!! Notwithstanding, however, this expenditure of £360,000, or the £250,000 that Mr. Lister informed us was written off as lost, it is abundantly plain that no amount of extravagance, or ill-advised expenditure incurred by an inventor, can furnish any ground for imposing a monopoly

upon the public, or for granting a patent by which an inventor can make demands of any amount he chooses, and therefore I repeat that patents are granted to inventors for (mark the criterion) discoveries that are ingenious and of public utility; and if they be granted for some discoveries because of these qualifications, it is impossible to see any just grounds upon which they can be refused to all and every discovery that does possess these qualifications.

If, therefore, patents or rewards or monopolies are justly granted to improved machines for brushing boots and shoes, why should a patent and reward be refused to a discovery such as Dalton's atomic theory? If a patent is justly granted for dye stuff for dyeing whiskers that evince a tendency to a gray colour, why should a patent and reward be refused to Harvey's discovery of the circulation of the blood? If a patent or reward is justly granted for crinoline skirts, why should a reward be refused for the discovery of vaccination? If patents are justly granted for improved machines for hatching eggs, why should a reward be refused for the discovery of the identity of heat and dynamic force or work? If a patent is justly granted for the discovery of a new wig, why should a reward be refused for the discovery of chloroform or of carbolic acid? If patents are justly granted for the discovery of scented soap or for a door handle, why should rewards be refused for the discovery of latent heat, or for the discovery of the composition of water, or for the discovery of the length of the pendulum? If patents or monopolies are justly granted for wool-gathering machines, or for machines that do something or other to velvet nap, upon which Mr. Lister at last meeting placed infinite stress, why should rewards not be obtained by the discoverers of the properties of the mariner's compass, or for the discovery of logarithms?—although, no doubt, there are persons that pander to the tastes of those that place infinite importance upon such gewgaws and cobwebs as are produced by the former discoveries, and who are wholly unable to appreciate or to see any value whatever in the latter. If patents or rewards are justly granted for the discovery of improved buttons, why should rewards be refused for the discovery of the law of gravitation, or for the discovery of the differential and integral calculus? Do the discoveries of machines for brushing boots and shoes, of scented soap, of buttons, of wigs, of wool-gathering machines, or velvet nap machines, or of machines for hatching eggs, display more ingenuity, or are they of greater public utility, than the discoveries of the law of gravitation, the identity of heat and work, of the

circulation of the blood, of vaccination, of anæsthetics, of carbolic acid, of the atomic theory, or of the differential calculus? The former of these discoveries cannot be possessed of exceptional ingenuity, as such discoveries abound on all sides and on all subjects, and from that very cause are not exceptional,—yet they are rewarded with the distinction of a monopoly. You cannot look out of the window without looking through glass that is involved in numerous patents. You cannot look through the room in which you may chance to be, without seeing probably a gasalier almost made of patents, without seeing patent picture cords, patent door handles, patent door hinges, patent paint on the walls. You cannot sit down on a chair which is not patent in its castors, or in the hair with which it is stuffed, or in the material with which it is covered, or in the machinery with which the hair or the covering material is prepared. You cannot walk across the room without treading on a carpet that is not patent in some respect or other, and probably in many. The cab in which you drive to the railway station is patent in its springs, or its wheels, or door handles, or the lining, or in its lamp, or in all. The carriage in which you travel on the railway is full of patents. The engine which draws you is, or has been, on all points, trammelled with patents. You cannot leave the train temporarily during a long journey without being pestered with patents. You cannot take a run into the country without encountering patent fences, patent ploughs, patent harrows, &c. The very beasts of the field are tormented with patents: the sheep are smeared with patent grease, the cows are milked with patent milking machines, the grouse are killed with patent shot, and the deer are shot with patent rifles. The farm homestead is blockaded with patents: the pigs are fed in patent troughs, the bullocks are fed on patent oil-cake, the hens are supplied with patent drinking fountains, the milk plates are patent, the cheese press is patent, the churn is patent, the washing machine is patent, the straw cutter is patent, the thrashing machine is patent. Sometimes, indeed, you meet patent wives,—I mean housewives.

If we were deprived of the discovery of such inventions, which there is no reason to suppose we would have been, though patents had never existed, because all that is worth would still have been devised, but even if we were so deprived, what would we suffer? We might, perhaps, at the worst, not have our boots quite so black; we might be unable to prevent our whiskers from becoming gray; we might, perhaps, be obliged to wear cloth not so fully double milled; we might not be able to luxuriate in purple velvet and fine

wool; we might, probably, be obliged to hatch our eggs in the old-fashioned way;—in short, we might be obliged to live in plainer houses, some of us might be obliged to wear dress that is not quite so fast, and we might be obliged to live on plainer food; changes which moralists and medical men all tell us would be attended with much advantage. But even though we were deprived, wholly deprived, of the discovery of all the inventions ever patented, humanity would not be lowered one iota in the ranks of civilization.

Deprive us, however, of a knowledge of the law of gravitation, deprive us of a knowledge of the identity of heat and work, of a knowledge of the circulation of the blood, of vaccination, of chloroform, of carbolic acid, of the length of the pendulum, of the differential and integral calculus,—discoveries which have received no State distinction and no State reward. Deprive us of discoveries such as these, and we would suffer a loss indeed. What is the trumpery discovery of machines for hatching eggs, in contrast with the discovery of the atomic theory? What are the trumpery discoveries of the separate condenser and the hot blast, in contrast with Newton's great and grand discovery of the law of gravitation, and Harvey's discovery of the circulation of the blood, of which the former discovery explained the whole solar and terrestrial system, and the latter, the whole system of the human frame; or what are the trumpery discoveries of wool-gathering machines, of velvet nap machines, or of soap bubble machines, in contrast with the discovery of the differential and integral calculus—a calculus by which all the discoveries in pure science, all the exact learning of the world, and great practical results bounded only by the universe, have been advanced with giant strides? If we were deprived of such discoveries and the contemplations to which they lead, we would be degraded by one fell swoop to the level of savages.

While these noble discoveries, which are full of ingenuity, full of public utility, and of unalterable importance, go unrewarded, no defence whatever can be pleaded of patents and monopolies for inventions, of which those possessing ingenuity and public utility are numbered by units, those possessing neither the one nor the other are numbered by thousands, and none of them are more than evanescent things of the moment. It is impossible, with justice to discoverers, and without great injustice to the public, that such monopolies can be maintained.

Dr. Robert Bell.—Though some of the arguments adduced by Mr. Lawrie are very good, yet others I consider very flimsy, and I beg to correct Mr. Lawrie on some points. He seems to

think that Jenner was not rewarded for his discovery of vaccination; but he received some £30,000 from Government. As for patenting the circulation of the blood, the thing is absolutely absurd; and the patenting of the law of gravitation is another very absurd thing.

If the patent laws were extinct, then the great incentive to men of genius to develop and mature ideas which, when put into practical use, may prove to be of infinite value to the community, would be stamped out. I say, that if the project of abolition is carried into effect, Britain no longer will be the wellspring of inventive talent. No longer will she stand foremost among the nations as the introducer of so many new and useful and ingenious machines, of which hitherto she has been so justly proud. Let us, then, stand up for a patent law, but let that be a reformed and improved law; for, as it now exists, it is a great tax on a man's ingenuity, and I hold that that ought to be encouraged as well as protected. What right has the Government to be overpaid for work which is often very imperfectly performed? No; I maintain that it would pay Government better to take no profit for giving protection to patentees; and if even by a slight loss it could encourage inventive genius, it would indirectly reap richer benefits. Moreover, it would be most desirable that an international patent law should exist; and I am convinced that this could be obtained, if properly gone about.

If protection is taken away from inventors, surely authors must lose their protection also. If the patent law is abolished, it stands to reason that that relating to copyright must go too. But the abolitionists tell us that they do not wish the inventors to go unrewarded. Oh, no; the State is to do that! Then, I ask, what right have I to pay into a fund to reward an invention, the profits of which will be reaped by only a limited part of the community, so that these few may have their pockets filled at the public expense? It would be quite a different thing if the invention was one which alleviated suffering and benefited humanity—*e. g.*, chloroform. Then such a man is bound to give out his invention to his fellow-creatures, irrespective of reward, and find ample return in the good which he sees he has done. Nevertheless, that man ought to receive a reward from the State, as it is the public as a body who are benefited, and not a limited few. When the pocket alone is touched, things are to be viewed quite differently; and he who is the means of enabling others to become rich, has certainly the first claim to be tangibly and sufficiently rewarded for his toil and anxiety.

Mr. James Stirling, having been introduced by the President, said:—

I beg to tell you at once, gentlemen, frankly, that I disapprove entirely of all patent rights; and I disapprove of them upon this ground, that I consider they are an unjust and injurious interference with the liberty of the subject. I know that those who think with me are often considered to be somewhat felonious in their nature,—that they are disposed to rob men of that which really belongs to them. But I, for one, and in name of those who think with me, repudiate this charge. We have no desire to deprive any man of that which is his own really and justly. Give every man his own:—*suum cuique tribuito;* but, gentlemen, we protest against the State giving to any single individual an exclusive privilege, by which he is entitled to interfere, as we consider unjustly and injuriously, with the free exercise of our liberty of thought and action. Mr. Lister, as I saw by the papers, put the subject upon what I consider to be a right footing, when he said that patents can only be defended if they are proved to be of general utility,—of benefit not only to the patentee, but to the public. The end which I have, and which we all have in view, is to give the greatest possible encouragement to improvement. Some think that this can best be done by natural means; others think this end will be best effected by artificial means and appliances. Now, my opinion is most decided, that in this, as in all other cases, our best wisdom is to stick to nature, to rely upon natural influences alone, because nature will never deceive and will never leave us, but will do whatever she has undertaken to do. The great fallacy which lies at the root of all patent right is this, that men suppose that all improvement proceeds from a certain small number of men who call themselves inventors. This I believe to be a fundamental and fatal fallacy. The spirit of improvement is not the property of any few men, or any class of men. It is the universal possession of the race; it is an instinct of our nature to improve. We cannot exist without improvement. It is absolutely necessary for every man in business that he shall and must improve. If he does not improve there can be no progress, there can be no success,—especially in a country where competition is so great. Any man who does not improve must very soon be left behind in the race of competition. I dare say there may be many amongst you here who are engaged in the practical exercises of production. I would put it to you, Is it not the case that the whole bent of your energies is how you shall improve your business,—how you shall improve all the different

processes in which you are engaged,—how you shall lessen the cost of production, and increase the efficacy of your processes? This not only is so, but it must be so, if you are to exist as producers in this country. It is not the few hundred or few thousand improvements, which are patented in this country, which make up the sum total of our progress; it is the thousand and one improvements which are made day by day, and hour by hour, in every workshop in the country, by ordinary men, in the ordinary pursuit of their business. It is these multitudinous improvements which make up, in the aggregate, the sum total of the great progress of our national industry. And there is this advantage, there is this beauty, in this natural course of improvement, that it leaves freedom to every man; the unrestricted progress of one man does not interfere with the progress of another. On the contrary, the improvements which are made by one assist the improvements of another. But under the patent law, it is quite the reverse. There, the restrictive privilege, which is granted to one, can only be exercised by restricting the natural liberty of every other citizen of the country in the free exercise of his energies. You had the other night here Mr. Lister, who seems to me to have argued his cause with great fairness, and in a most gentlemanly manner. He made no improper imputations upon other people's motives. He allowed that much might be said upon both sides. I would wish to reciprocate such conduct. But he did not by any means convince me. Mr. Lister appears to be a man of very great talent, and of immense perseverance,—to be such a man as would certainly succeed in any business without the benefit of exclusive privileges. But what has been the result of this gentleman's work during the last twenty years? He tells you that in sixty-four different paths of improvement he has taken out sixty-four patents. Now, what does that amount to as regards the public? It is, that Mr. Lister has set up sixty-four different obstructions in the path of improvement. It is neither more nor less than that. He not only charges toll upon sixty-four different paths, but he says, "Farther upon this path you shall not go." No man, whatever may be his talent, whatever his desire to advance farther in these sixty-four different directions,—no man in Yorkshire can advance a single step. More than that, no man dare proceed in these directions for the next fourteen years. I must say it appears to me a most preposterous idea, that any man who has stuck up sixty-four different obstructions in the path of progress, in the woollen industry of Yorkshire, should come down here and tell us he has done a vast deal to advance the improvement of

the Yorkshire woollen manufacture. I can only understand it, I can only explain it in this way: when a man for twenty years has brooded over one idea, he becomes so possessed with it, it takes such a hold of his mind, that it destroys the natural faculties of his understanding; in fact, it becomes more or less a species of monomania. More than this, Mr. Lister has told you that if you do away with patent rights, you will have no inventions at all. Now, I think that is "coming it rather too strong." I think, in the year 1800, there were only ninety-six patents altogether in the kingdom of England. Surely Mr. Lister will not tell us that for 6,000 years, that before the year 1800 there was no such thing as inventions,—that before the idea of patents was conceived there were not the plough, the spade, the screw, the printing press, gunpowder, &c. These were all inventions; yet none of them were owing to patents. You had the whole civilization of the ancient world, you had the whole civilization of modern times;—all that had taken place through that same spirit of improvement, which, I say, is the common property of the race, without the help of the patent laws. Why, gentlemen, it is a libel upon Providence to say that you will have no improvements without patent laws. Surely, if our Almighty Maker intends that we shall advance in civilization, and shall have improvements, He is able to suggest means for attaining that end without the intervention of patent laws, or patent agents. There is one consideration which I think is sufficient to settle this question of patent law, if men will look upon it in a candid manner. It is this: that where the public is looked upon as a corporate body, and as a producer, there patents are not allowed. The greatest authorities have held that the Queen is not bound by patent laws, and the Queen represents the public. Accordingly, one of the recommendations in the report of the late Commission which sat upon the patent laws was this, that even if patents should be continued, they should not be allowed to interfere with the public service. Now, I think that is giving up the whole case of patents; because, if they are not for the benefit of the public in a corporate capacity, undoubtedly they are not for the benefit of the public in an individual capacity. So much as regards the public. But does patent law even benefit the inventor? I say it does not. We know very well that a great many of the patents taken out are not great inventions. I think upwards of 90 per cent. are allowed to be perfectly frivolous and contemptible. Then there are some which are absolutely absurd. If I recollect right, every year there are some dozens taken out

for squaring the circle, and about a dozen more for perpetual motion. I think, Mr. President, these are not very meritorious inventions. Indeed, it seems to me we have still amongst you some of the descendants of the philosophers of Laputa. We have amongst us men who would be willing to take out patents for extracting sunbeams from cucumbers. But as to the great inventors, I admit we have men of genius who apply themselves to useful purposes. We have such men as Brunel, Sir William Armstrong, Platt, and Scott Russell. These are men whom I admire,—whom I deem most undoubtedly to be men of great merit. But these men will have no patents; they repudiate all patents. They say that patents are absolutely obstructions, and a nuisance to them. They have told you this before the Commission. They have not only to meet the obstructions of honest patents, but they have dishonest patents to meet. There are men who trade upon obstruction. Whenever a discovery is made in science, these men look about how it can be applied to practical purposes, and they take out patents, and they specify every possible means they can devise where these may be brought into use; not for the purpose of using them themselves, but to lie in wait for the honest producer; and when he appears, they spring upon him and claim from him black-mail for their patents. This has been told by these gentlemen themselves. It is not my story, but theirs. The fact is, these men dig pitfalls and set traps, in order to catch the unwary. Mr. Platt was sometimes obliged to patent his inventions, because these men would steal them, would patent them, and then come and offer to sell him his own inventions. That was a statement of fact given to the Commission, which I believe to be perfectly true. Now, it has come to this, that when a man of genius really sets himself to make improvements for the benefit of the country, his great difficulty is not how he shall best control the laws of nature, but how he shall best baffle the law of patents. After these men of genius have taken out their patents, what is their reward? Then begins their battle for existence. They are forced into perpetual litigation of the most intricate and most expensive kind, without which it is impossible they can maintain their patents. I think, then, that neither with regard to the public, nor with regard to the patentee, can patents be said to be of any use. But you have been told by Mr. Lister and others, that unless you preserve your patent laws, it will be impossible to compete with foreign countries who have the good

sense to retain their patents. I am surprised that a man should come 200 miles to make such a statement as that. It is precisely the reverse. If we do not do away with those clogs which are now preventing our advance in the industrial arts, it will be impossible for us to compete with foreign countries which have thrown, or are about to throw, away those laws. Take Prussia, for instance, which in our day we may call Germany. In Prussia there are but few patents altogether. In that little book of Mr. Macfie's, on the subject of the abolition of patents, which I hope you have all read, or will read attentively hereafter, you will find a paper with the signature of Count Bismarck, most remarkable as coming from such a man, in which the subject of the patent laws is most ably handled, and in which the abolition of them is most decidedly recommended. I consider, therefore, looking to the signature attached to that paper, that you may take it for granted that in all Prussia, and in all Germany, very soon there will be no such thing as a patent. Then, if you take the kingdom of Holland, within a fortnight of to-day there will be no patents. On the 1st January, 1870, the patent laws cease in the kingdom of Holland. Then, if I were to ask, What is the most industrious, and most successful, and most prosperous of the Continental States of Europe? no doubt you would answer, Switzerland. Well, Switzerland has no patent law. Then, as to France, it is true that the Government of France has as yet made no proposal for the abolition of patents; but in France there is a power which is above the Government. It is the power of the *savans*, the power of the men of thought. Now, they have declared against patents. I will mention only one name; but that name is a host. It is the name of M. Chevalier, who has declared himself publicly as strongly against the principle of patents, upon this ground, that he considers it interferes with the liberty of industry. When such a man as M. Chevalier, in the heart of Paris, declares himself against the system, you may depend upon it that the beginning of the end is at hand. True, there is one country where patents do flourish. It is the United States of America. I think, however, you will agree with me that America is not the country from which Englishmen will be pleased to take lessons in political economy. A country that is yet wallowing in the mire of protectionism is not one to teach political economy. It is not a light to guide us on to progress, but rather a beacon to warn us off the rocks and quicksands which we should avoid. I cannot sit down without making one appeal to you to consider what is the principle that has been our guide in all the best legislation of

modern times. That principle is to abolish all artificial helps; to trust to natural influences only. That, gentlemen, was the great principle of our free trade legislation—the best and most beneficent legislation of modern times. I say, apply that principle to improvement. Abolish all artificial helps and props, and trust to natural influences alone. I know that that is not the popular opinion; but I have lived long enough to have seen various reforms carried, which at one time I despaired of. I am not without the hope of living to see the tide turn, and sweep away the unjust and injurious restrictions of the patent law.

Mr. Schuman.—It has been argued that patent laws are injurious, and ought to be abolished because they create monopolies opposed to the principles of free trade. But this is an abuse of the word "monopoly," because the privilege extends only to the creation or combination of the individual patent, whose value is measured by the standard of the advantages it offers, and the dealings in it are fully subject to the free trade principles of supply and demand, for every patent is a special marketable article. Moreover, time, money, and ingenuity are invested before a patent can be created; and if property rights in such investments are not legal, this special and most useful branch of industry must perish, and the legal rights to all properties might be questioned!

Some abolitionists here reply that the present advanced state of industry and the laws of nature, acting through the inventive faculty innate in man, will create the advancement of the arts and industries, whilst the disadvantages to certain manufacturers (especially those who would like to have for nothing the results of the genius of others) of a patentee having the sole possession of a valuable invention for a time, will no longer exist; but I would here remark that though the laws of nature operate to provide crops and food, yet no agriculturist would till the ground, sow the seed, and battle with all emergencies till ripening, if at harvesting the produce were made public property. Humanity may aspire to such a state of disinterestedness, for the history of all ages has furnished examples of noble lives entirely devoted to further the well-being and the happiness of the whole human race; and doubtless the spread and advance of civilization, in the highest sense, is to realize such a general state of society. At the present time, however, we are but feebly endeavouring to call into life the best energies of man; and in this birth-struggle and awakening to encourage him to go forward, to remove the barriers with which ignorance and prejudice have surrounded him, by the path of justice to all. Gradually he may

pass into that higher state already foreshadowed by the noblest of his race; whilst in the practical present, other interests than the toils of the ingenious, more able because with more to spare, should lead the van to this most desirable goal. *The argument*, "That by conventional rewards we give a factitious impulse to the inventive faculty, and destroy the equilibrium of our capacities," need not alarm us, for, as hitherto, the laws of nature and of self-preservation will rectify such leanings; just as the laws of free trade will cure the other evil pointed out (by Mr. Stirling) of solid workmanship sacrificed to flimsy ingenuity.

Mr. Macfie proposed that State rewards in money and medals be given for meritorious inventions by an inventors' tribunal and special jury; and that Parliament should vote annually a certain sum for that purpose.

Such a scheme is not just; as it would place the tribunal in the position of a buyer who first takes possession of the article and afterwards fixes the price, leaving the seller (inventor) without legal redress; for, whether they would pay him anything or nothing at all, they take possession of the invention. Besides, this scheme would encourage such a host of applicants that it would be impossible to do justice to all; and it might also create unlimited jobbery, without supplying any practical guide for those interested as to the results of the application.

Abolitionists refer to Count Bismarck's arguments for the extinction of patent laws. But in truth Prussia, geographically surrounded by several German principalities, to whom the fostering of patent laws can be of no value, only wishes to remove all barriers, so as to facilitate their ultimate absorption within herself.

Though existing patent laws have given rise to numerous cases of litigation, this does not prove that the economic principles of the patent laws are wrong, but that the law-makers have not yet devoted that amount of time and attention to the subject which is necessary to obtain a sufficient grasp of it, and to enable them to devise laws with a due regard to the public importance of the subject, and to strict justice towards the patentee. On these grounds I support the motion, praying for the appointment of a Royal Commission to investigate the present state of the patent laws.

MR. JAMES ANDERSON classed the patent laws with all monopolies and every sort of protection, as alike adverse to the interests of humanity and civilization. The universal question of the pro-patent party is, How are inventors to be remunerated for their merit if the patent law is done away with? Well, what are the

merits of inventors? On examination you will find the merits of inventors and the public very much confounded, the inventor getting credit for a great deal more than belongs to him. To illustrate this most important point, let us suppose that Alexander Selkirk, the original of Robinson Crusoe, remembered how to make yarn by twisting fibre with a stick and then winding it up. But never having learned the stocking loop, he could not make a pair of stockings. But knowing that the thing could be done, he applied himself to the rediscovery of the loop, and by perseverance succeeded, and made a pair of stockings for himself. Selkirk's merit was not doubled by the landing of another man on the island. The fact that another pair of stockings was required, did not make the discovery of the loop more difficult, or in any way increase the labour of the discovery. The merit of the additional demand for stockings belonged entirely to the arrivals, the demand increasing with the increase of population; consequently the merit of the demand belongs to the public. The patent law goes on the principle that the inventor is in proportion to the population—that it is thirty million times more difficult to rediscover the stocking loop in Great Britain than in Selkirk's island. Keeping this principle in view, let us look at the famed Bessemer's patent process for refining iron. Suppose that Bessemer discovered that the new metal zirconium was refined by blowing air through it when in a melted state. The merit is exactly the same as the discovery that iron is refined by the same means. If Bessemer's idea was applicable to zirconium only, you would have heard very little of his merit, on account of the small quantity of zirconium used by the public. But being applicable to iron he became famous, and the patent laws make him a millionaire. Yet Bessemer has no more merit from the enormous consumption of iron than any other of Her Majesty's subjects. The millions of tons of iron now used, is the result of the labour and toil of hundreds of thousands of human beings extended over thousands of years, and with this Mr. Bessemer has had little to do. Yet the patent laws have given him jurisdiction over all the iron-making in Great Britain, over all the labour of present and past generations.

There is just one argument of any weight that can be brought forward in favour of the patent law; that is, the tendency that manufacturers will have to keep their processes and inventions secret should it be abolished. If it can be shewn that important secrets cannot be kept from the public, then it seems to me that the question is settled. The object of the passing of the patent

laws was not to encourage invention, but to induce inventors to make their processes known, hence the word "patent," open. It is only in very modern times protection to inventors was thought of, and, I suppose, because the secret argument had been found to fail, it being notorious that if a man thinks he can keep his secret for fourteen years he will not patent it.

In regard to chemical secrets, the relation of the public is now completely altered from what it was at the time of the first passing of the patent law. It would be next to impossible to keep a chemical secret for any lengthened period in modern times, and experience shews that all mechanical secrets ooze out in time in spite of every precaution.

There is another phase of the patent laws which seems to me most iniquitous. They are framed on the basis of assisting and protecting the strong, and crushing the weak. The man who is strong and powerful in invention is taken by the patent laws and treated as if he were a toddling child, needing the most tender care and the greatest protection.

Mr. Lister came here last Wednesday to advocate the cause of those laws which have so much petted him, and which he stands so little in need of. This giant of British inventors can throw off idea after idea, invention after invention, machine after machine, with the rapidity of a printing press. With absolute freedom of invention, hard is the fate of those who have to compete in business with this terrible concentration of inventive energy. But woe betide them, with the remnants of a slave law tying up their freedom of thought and their freedom of action, and giving him a fourteen years' monopoly!

Mr. W. R. W. Smith.—It struck me, from the extensive operations which Mr. Lister had carried on for a great many years, that it would be interesting to have from him a statement of his views on the subject under discussion. I therefore wrote him, and had the pleasure of bringing him before you, and now I feel almost necessitated to speak in consequence of the onslaughts which have been made upon him this evening by Mr. Lawrie. I cannot by any possibility take up your time by following Mr. Lawrie through the farm-yard, the doctor's shop, and elsewhere; all I will say is, that Mr. Lawrie never knew anything of wool-combing, or he would never have spoken so slightingly as he has done of Mr. Lister's invention. I have known Mr. Lister's name for thirty years; for twenty years I did not know him personally, but I have done so for the last six or eight years, and his reputation in Brad-

ford is perhaps the best answer that can be given to all that Mr. Lawrie and others have said in his depreciation. As an old man in the town once remarked, "Why, Sammy Lister has made more gentlemen in Bradford than any man in the country." Mr. Lister told us, Government paid £10,000 to Arkwright for his wool-combing machine, although it never combed one pound. That machine ruined one inventor after another, and caused so heavy a strain on Mr. Lister's partner, Mr. Donisthorpe, as ultimately to impair his mind. The machine was fifty years in coming to its present perfection. It is said that Mr. Lister has taken out sixty-four obstructions, but it so happens that Mr. Lister has patented upon patents; and this machine has not only changed the whole aspect of the trade, but has brought wool into use from all parts of the world that could hardly otherwise be used. It has cheapened the process, brought the trade into a condition totally different from what it ever was in during the last thirty years, and now gives employment to millions of people in this country and the Continent.

I will present to you, in very few words, another resolution on this subject, and simply because I think the position I am about to bring before you has not been touched on by any previous speaker. It is one, I think, which will at once shew you that at the present moment we are necessitated to take some action; and the question is, What is that action to be? Mr. Macfie brings forward an argument of no small magnitude, and one that will force on a change very soon, whether we will or no, if from nothing else than the action of the patentees themselves. Mr. Macfie's argument is: If you continue to burden your manufacturers with a patent law, and other countries refuse to have such a law, how can your manufacturers compete if you admit the manufactures of these countries? Now, I have said that we must have a change very soon, whether we will or no, if from nothing else than the action of the patentees themselves in defending their position; and this change is much nearer than we think. Mr. Smith here read the following paragraph from the *Economist* of December 18:—

"Vice-Chancellor James's decision in Emslie *v.* Boursier, a patent case, is a reminder of the immense practical difficulties in the way of a good patent law. The plaintiff, who had an English patent for manufacturing sheet tin, complained of the infringement of it by the import of similar articles made by the defendant in France, who was there a patentee of the same process, and the Vice-Chancellor granted an injunction, holding that the sale of the goods in England was an infraction of the patent as much as the erection

of a manufactory in England. This is surely a very strong case. Patentees are not only to have the privilege of stopping other manufacturers within their limits, but the law will interfere with general business,—with the sale of goods which have been legitimately manufactured in the ordinary course of trade. There is little apparent offence to equity in the present decision, as the original sale of the patent right to the defendant specially excluded England; but what if innocent third parties had been the importers of the goods? Is the English creditor of a French debtor not to be allowed to receive payment in sheet tin, or any other patented article?—for that is what the decision, if universally applied, will amount to. The confusion and litigation that would be the consequence are indescribable, though they seem inevitable from the patent law which the Vice-Chancellor may be trusted to have interpreted with accuracy. With increasing international trade, and facilities of communication, it will be practically impossible to enforce separate patents for particular countries. The manufacture cannot be stopped, unless a patentee has all the patents, and there are few articles which cannot be successfully distributed if once lawfully made."

Mr. Smith continued:—Now, I neither advocate from this the abolition of patents, nor do I see in it anything else than a help to a solution of the question, inasmuch as so perfectly unerring is the principle of free trade, that if we apply it to the position of the patentee as to other traders, it brings us out of the difficulty. We are all agreed, even the abolitionists, that we must reward our inventors.

The question is, How our inventors are to be rewarded. Mr. Macfie says, "By a system of rewards;" but from his point of view we may dismiss this as impracticable. Suppose, however, that we continue a law somewhat as at present, only admitting freely the manufactures of other countries under this patent, and without having paid the patent license, it at once becomes apparent that either our manufacturers must cease working, or obtain some relief against the patentee's license. Now, our present patent law is based on compromise. The inventor says, "I have a secret, the result of much brain work, that will cheapen and improve the mode of working in a certain trade;" and the abolitionists may say what they like, but that has been virtually the effect of all patents, even during the existence of the patent. Their argument here is knocked out of place by stern facts; and the country replies, "Well, tell us this secret, and you can charge for the use of it for fourteen

years, on payment of certain fees." Seeing, then, this compromise has been our rule, it is no injustice if the altered trading condition of the country bring us to the necessity of a new compromise, and force the inventor into the general rank of competition as under free trade. Suppose, then, that an inventor has obtained a patent for some process or machine, and very shortly a product from this process or machine comes to this country and competes, to the loss of our manufacturers paying patent right. We could then, in a simple manner, bring Mr. Macfie's system of rewards into play through a jury or court of experts, who might have facts to go upon in forming their decision, with which facts the inventor would only be allowed to deal; and all fear would disappear of that jobbery and partiality, or complaint of injustice by the inventor, so ably noticed by Lord Stanley as a valid argument against Mr. Macfie's system, and which would retain in our midst a system of encouragement to the inventive talent of the country, while they, the inventors, are only put on the same footing as all other traders in our trading system,—and they are as much traders as any of us. I am disposed, however, for some law of encouragement, inasmuch as we have exceptional conditions in our extensive manufacturing operations, and, above all, in our field of materials, requiring a continued exertion of this talent to their full development. Doubtless the arrangement of such a law is surrounded with difficulties; but it is clear that, referring to the decision that I have read, we will be forced into some compromise further with the inventor, or into the abolition of patent right altogether. It is from this point of view, therefore, that I take exception to your resolution, Mr. President, and think that we should endeavour to pass a resolution, in which we should be unanimous; and I am the more impressed with this view of the case, as, in pledging ourselves not to approve of abolition, we may be wrong,—we may yet come to see that the principle of the patent law is wrong. At present, so much can be said on both sides that we are left in an unsatisfactory condition; and, looking to the current of thought in the present day to set everything free, it may be wiser that we attempt a compromise, than take up a position to make that compromise difficult. MR. SMITH submitted the following motion:—"That in the opinion of this Society, from the progress of the arts and manufactures in the country, and the alteration in our trading relations with other countries, the time has arrived for the reconsideration of the patent laws." To this, however, he would append Mr. Hunt's third resolution, viz.:—"Any Parliamentary inquiry, instituted with a view to improved legislation, should be conducted

so as to collect the fullest possible information from the various important manufacturing centres of the kingdom, and from all classes in any way concerned in inventions or patents."

Mr. Mayer seconded this amendment.

Mr. W. M. Neilson.—A few facts are of much greater value to us than many opinions. I attach great weight to Mr. Stirling's opinions, knowing his opinions on other matters; but I must give it as my humble opinion, that the statement of Mr. Stirling as to patents having been found to be, and that they are now, obstructions and impediments to progress in the arts, is not the fact, but contrary to the fact. My thorough conviction is, that inventions, and inventors, and patents for inventions—I put them all together as they are—are pioneers instead of obstructions, and open up the way and lead us on to further improvements and inventions. Of course we have all differences in our opinions; but I would like if, instead of giving loose opinions, parties had brought forward facts to the Society, leaving members to form their opinions from them. The time is short, but I will be very glad to take Mr. Stirling up upon this point, and allow him to choose ten patents as great obstructions to the arts, and I will bring other ten, and prove that they have been the greatest pioneers in progress by which this country has ever benefited. Another point: Mr. Stirling takes us back to 1800, when there were very few patents. I am sorry Mr. Stirling thought that a satisfactory time. No doubt there were good things then. There was the wooden plough, which certainly scraped the ground a little bit, and took a few more horses, and perhaps farmers had only about half the amount of grain from the land; but we cannot have these times to live in: we must have our iron plough and our patent plough, with half the power to work it, and ploughing the land in a proper way. In these good old times they certainly had ships, with a good big stone at the end of a rope for an anchor; but we must have patent anchors to hold ships, and large ships too. No doubt we had a few patents some seventy years ago; but look at the progress this country has made since 1800! and I ask him if the whole history of this country, or of the world, has ever shewn such enormous strides in progress as this country has manifested since 1800? I should like, with Mr. Stirling or other gentlemen, to table a few facts in reference to this point. Don't let us argue or discuss upon the present state of the country. Find out the cause of the progress of the country; and if inventions and inventors, as I humbly submit, have been the means of bringing forward those magnificent improvements which have so enormously benefited

this country, I ask whether it is our duty to encourage or discourage these inventors and inventions?

Mr. Day having briefly spoken in reply,—

The President observed that there had been three separate motions made (the one by Mr. Hunt containing a series of three resolutions), but as they wanted to find out what the Society wished to express in reference to this subject, it did not signify as to what was any man's particular resolution. He wished to submit a modified motion, which did not commit the Society to the expression of an opinion that patents should be maintained. His own first resolution committed the Society against abolition, while that of Mr. Smith did not. The modified motion was as follows:— "That, in the opinion of this Society, the progress of the arts and manufactures in this country, and the alteration in its trading relations with other countries, render necessary a reconsideration of the patent laws, and they would hail with satisfaction the appointment of a Royal Commission to collect information at the great centres of manufacturing industry, and from all classes of persons in any way connected with inventions or patents." The advantage of a Commission was, that they would come down here and take an examination in Glasgow. A Parliamentary Committee would not do that. Perhaps this motion would please the Society.

Dr. F. H. Thomson seconded the motion as modified.

The President then moved, seconded by Dr. Thomson, "That for the purpose of watching the progress of legislation, and, if necessary, preparing a memorial or petition in conformity with the Society's resolution, the following gentlemen be appointed a committee, with power to add to their number:—The President (Dr. Bryce), Dr. F. H. Thomson, Sir William Thomson, Dr. William J. Macquorn Rankine, Walter M. Neilson, J. G. Lawrie, John M. Rowan, Edward C. C. Stanford, W. R. Hutton, James Robertson, James Anderson, W. R. W. Smith, and John Mayer—Mr. W. M. Neilson, Convener."

Mr. Hunt wished that the first of the resolutions he had proposed should be put to the meeting, as some might wish to adopt it, viz.:—"In the opinion of this Society, the time has not arrived when the progress of the arts and manufactures in this country would be promoted by the abolition of patents for inventions."

The vote was then taken by a shew of hands, when Mr. Hunt's resolution was lost, and the two motions last proposed by the President were adopted.

This terminated the proceedings.

II.—*On the Principles affecting the Solvency of a Life Assurance Company, and the Best Means of Protecting the Public against their Violation.* By MR. JAMES R. MACFADYEN, Fellow of the Faculty of Actuaries in Scotland.

Read before the Society, January 26, 1870.

LIFE Assurance seems to us one of the most fitting subjects that can be brought before such a Society as this. Based as it is on the widest mathematical laws, and yet in its application requiring not merely the scholastic acquirements of the mathematician, but a double portion of that tact and energy which are generally supposed to be the characteristic of the business man,—opening on the one side into the profoundest of scientific problems, and on the other, into questions of finance, investments, and the thousand details of ordinary mercantile life,—it is peculiarly worthy of the attention of a Society in which science and commerce go hand in hand, each lending support to the other.

The shock to public confidence caused by the fall of the "Albert Company," the ordeal through which the "European" has just passed, and the certainty that before long we shall have legislation on the subject, still further shew the fitness of such a question being now discussed; and more especially of that portion of it which we shall take up to-night—viz., the principles underlying the solvency of a Life Office, and the best means of protecting the public against their violation. Life Assurance considered as an investment, the various systems of dividing profit, the amount of bonus received as compared with the price paid for it, the comparative advantages of participating and non-participating rates of premium and the like, are each matters of importance to the provident community; but the question of solvency, like Aaron's rod, swallows them all. It is the foundation—everything else is mere superstructure. We shall then devote ourselves solely to that question this evening; and the method we propose to follow in doing so is, in the first place, to shew what conditions are necessary to the solvency of a Life Company; and after having in this way arrived at distinguishing between essentials and non-essentials, and knowing precisely the vulnerable points, we shall be in a position to discuss as to what form of legislation

will best protect the public against the violation of these fundamental principles.

A Life Office is able to meet its engagements so long as it has realizable assets to the extent that will be needed to meet its claims as they fall due. The sum thus required represents its indebtedness to the assurers, and is the aggregate of the liability under every individual contract. The stake, then, that any member has in the Company, is the indebtedness under, or, as it is more commonly called, the "value" of his policy; and the question of solvency is simply, Has the Office in hand such a sum as will pay every assurer in it the present value of his policy? If it has this amount, even should it wish to discontinue business, any other Company would gladly take over its assets and discharge its obligations, and that, too, without rejecting those members whose lives were now uninsurable. If it has not this sum, it is bankrupt, even although it is quite able to discharge all the present death-claims upon it.

The whole matter, then, turns on the amount reserved as the value of every contract. If this sum be calculated according to sound principles, and be an item not merely on paper, but either money or what can be turned into money, the Office will not fail those who have trusted in it.

The formula for the value of a policy is, then, all-important in a scientific investigation of the subject.

Deducing this expression in a manner which, because it deals with the results of the future, is called "prospective," we find that the value of a policy is the difference between the sum that, sunk now, would with its interest discharge the claim when it arose, and the present worth of the future payments to be made by the assurer.

These payments, however, represent not merely the nett premiums that are absolutely necessary to be paid in order to meet the amount assured when it shall become due, but also include a further sum to provide for charges of management, contingencies, and, in most cases also, to be the main source of bonus. This addition, or margin, is usually called the "loading." If, then, in estimating its liability under its policies, a Company debit itself only with the sum that would be actually requisite to pay the amount assured at death, and credit itself with the *gross* future payments under its contracts, instead of the *nett* premiums merely, it will have anticipated the total worth of this loading; and there *will be no* fund to provide future working expenses, or to be a

source of profit; and, so far as this item is concerned, the Company is insolvent.

If a part of this loading only be discounted, and the remainder be sufficient to pay the future charges of management, the Company will be solvent in the sense that it will be able to pay its policies; but little or no profit can be expected by the assurer, as a great part of its resources will have been made away with,—not an enviable state of things certainly, when we remember that in most instances the policy-holder, in order to share in the profits, pays a considerable sum in addition to that which is required to meet the amount named in his contract.

The value of this item of loading, and the importance of keeping it intact, can be guessed when it is stated that, in "participating" policies, it averages about 25 per cent. of the nett or pure annual premium. If it be reserved; at every investigation period, the profit that has accrued on it for the past can be safely divided, and its whole future worth remains a perennial spring of safety and bonus.

The first and most urgent, then, of the principles affecting the solvency of a Life Office is, THAT THE WHOLE OF THE FUTURE LOADING AT EACH INVESTIGATION BE RESERVED INTACT.

It is scarcely possible to exaggerate the importance of this principle. If no part of this margin be divided till it be actually realized, a Life Company can stand almost any mismanagement in other points. There should, then, be no tampering with the future loading on the premiums.*

We next come to the second principle to be observed in estimating the reserve under a Life policy.

Since the Company assumes that a certain rate of interest will be realized on its investments, and gives the assurer the benefit of that rate, it becomes important that the interest anticipated as receivable be not greater than that actually obtained. It is obvious that, *per se*, the lower the rate of interest assumed, the greater the safety;—we say, *per se*, because there are modifications considerably affecting

* Some actuaries have considered that, in certain instances, such as when in a policy the commission payable to the agent has been commuted, it is admissible to discount this future loading to the extent of the commuted commission. No doubt this is correct; but as this method of treating commission is, in most cases, undesirable, through the empirical manner in which the commutation is arrived at, and as also discounting of future resources is a principle likely to lead to the most dangerous abuses, we do not consider it requisite to modify a rule so general, to meet the exigencies of cases so special.

our results. Still, on the whole, it may be safely considered that a low rate of interest will give a high liability, and *vice versâ.*

If it were advisable to give an opinion as to what is the maximum rate of interest that may be assumed in valuing the liabilities of a Life Office, we should say that 4 per cent. is not far from the boundaries of safety. It must be remembered that the tables on which the Office's rates are based assume that every premium is paid on the day it falls due, is invested there and then at the anticipated rate of interest, and that there are no losses on investments—things that in practice are, of course, incapable of realization,—so that a 4 per cent. valuation really requires more than that nominal rate to be made, in order that the realized interest do not fall short of the anticipated.

The second principle, then, is, THAT THE INTEREST ESTIMATED AS RECEIVABLE MUST NOT BE TAKEN AS GREATER THAN THAT WHICH IS CERTAIN TO BE OBTAINED.

The third matter refers to the table of mortality employed. As it is evident, whether it arises from faulty selection or otherwise, that a mortality greater than that allowed for, will (so far as this particular item can) render the reserve insufficient, it is necessary that we should lay down, as our third principle, that THE AVERAGE DEATH-RATE EXPERIENCED OVER A SERIES OF YEARS SHOULD NOT BE GREATER THAN THAT ANTICIPATED AND PROVIDED FOR.

The remaining principle affecting safety is not an actuarial one. You may retain all the loading, value by the most approved tables of mortality and rates of interest, but what if your reserve consists of "Pennsylvanian" bonds, or say "Chatham and Dover" stock, estimated at par? THE ASSETS (which, of course, must be equal in amount to the liabilities calculated by the preceding rules) MUST THEN BE OF THE WORTH PUT ON THEM. They should not be of a class subject to great and sudden changes in value. Of all concerns in the world, a Life Assurance Company's investments ought to be, and almost invariably are, the farthest removed from what may be termed speculative. I need hardly dwell longer on this fourth point,—it requires no comment. The value of realized assets is a matter that, in a commercial community, it is unnecessary to enter much into detail about.

It will be observed that we say nothing in our rules as to charges of management. Were he able to make use of it, which he certainly is not, to a policy-holder, wishing to determine whether the profit he might expect would be worth the price given for it, it would be

important, no doubt, to know what proportion the expenses bear to the *premium* revenue. But this is not an essential item in the question of safety. It is scarcely possible, without the grossest fraud, in an investigation term of ordinary length, to spend such a sum as will render a Life Company bankrupt; and if, in the recurring periods of valuation, the foregoing principles be rigidly applied, the check to extravagant expenditure will be sufficiently marked to prevent any danger on this score.

The whole amount of loading being reserved, the interest realized exceeding the amount anticipated, the mortality experienced being not less favourable than that provided for, and the assets being of the value put on them,—on these four things the security of a Life Assurance Office is based. Failure in one of these points merely, will scarcely drag down a Company, should no undue strain have been put on the other three. It is in this elasticity, and great variety of resources, that the strength of a Life Assurance Office consists. "*Quocunque jeceris stabit*" might well be its motto. Let some of its investments fail, the other three pillars will support it; let the mortality be unfavourable, and even let the interest be somewhat exceeded, the last stay will in many cases, Atlas-like, prop up the whole building.

Not, however, because we consider there is any probability, or even possibility, of its being called on to do so in capable hands, have we adduced this example, but merely as an illustration of the strength of the foundation on which the colossal fabric of Life Assurance in Britain has been reared.

In *loading*, *interest*, *mortality*, and *assets*, then, the security of a Life Office is bound up; and it is only by applying the correct principles concerning them to the formula we have previously given, that the proper reserve to be retained by a Society can be estimated. No empirical test can be safely followed for this purpose; and, did time permit, it would be a very easy thing to shew what fallacious guides are the many rules of this kind that the press has lately so lavishly given us. The expression for the worth of a policy is of far too Protean a nature to be bound in such rigid bands as a fixed ratio of any kind; and it is only by a valuation, by the expression we have given, that the Office's liability can be determined.

But a valuation may mean anything, according to the data employed. We must, therefore, particularize the elements of the formula by an application of the axioms we have laid down. Should their requirements be satisfied, the Office will be solvent; if

totally unheeded, it cannot be so; if partly neglected, it may or may not be, according to the grossness of that neglect.

In giving these four axioms, we believe we are furnishing all the relevant matter that the ordinary policy-holder can make use of. Many journalists, whom recent events in the Insurance world have caused to turn their pens in this direction, think otherwise. They have insisted on the publication, by the Life Companies, of a host of details that might be more or less valuable to the mathematician; but which, unless technical education became so widely spread that every man could be his own actuary, would be utterly meaningless to the community at large. What possible use can the public make of reports of the amount assured at each age,—the average duration of policies,—the numbers entering, and the other formidable-looking items that so many of the certainly "self-taught" writers for the press have been calling on the Life Offices to supply, as a test of their worthiness of confidence?

The confidence that would be inspired or withheld by the producing, or keeping back, of a number of unintelligible details, must be a plant of a very peculiar growth. It springs up, one knows not how—it refuses to flourish, one knows not why. These items, or rather some of them, would be, so far as they go, useful to the actuary, inasmuch as they will be required, should he wish to calculate an Office's liability for himself. The four axioms which we give would not furnish him with the means of estimating what this sum reserved ought to be, but would enable him to judge of the soundness of the principles employed in computing it. The first will, with the help of a great many more items, enable the *adept* to say whether the Company is solvent. The general axioms will supply this information to the learned and unlearned alike. Both suppose the returns are correctly made by the Office. It is necessary, however, to trust somewhere. We may accumulate check on check, but we must take something for granted as our basis. The earth may rest on the elephant—the elephant on the tortoise; but in the end we must place the tortoise on space. We do not, however, believe that the danger of false statements being made is a great one. The criminal law is too awkward an opponent to be lightly faced. What is told is usually the truth — the misfortune is that it may not be the whole truth.

We have said that the axioms we have given *can* be applied by the skilled and the unskilled alike. Will they both do so is, however, quite another thing. We are reluctantly driven to the

conclusion that a very large section of the public will not, and, indeed, cannot. This may seem contradictory to our previous remarks; but really is not. What is called "ordinary intelligence" is not by any means so ordinary as to warrant us in relying that men in the mass will be guided by it. Therefore, holding as we do, that Life Assurance is of such a special nature that every encouragement should be given to it, we consider that if it be possible to protect from risk of loss in it those who will not, or cannot, protect themselves, Government ought to do so. That it is possible to a very large extent, we have no doubt; and we shall now examine the various methods that have been suggested for this purpose.

One plan that has been proposed is to compel the publication of the accounts of the various Life Offices, with machinery to enable the policy-holder to have these statements verified, should he think it necessary. Of this nature was the Bill introduced into Parliament last session by the Honourable Mr. Cave.

Another proposition is, to compel the deposit with Government, or the investment in trust for the policy-holders in Government securities, of a certain proportion of the assets. This principle formed the distinguishing feature of a Life Company now extinct (the "Consols"), and since again has been taken up by another Office. This is also the principle of a measure passed last year in the State of New York on the subject.*

A third suggestion has been, that Government itself should extend its scheme of industrial assurances till it embraces all sections of the community.

A fourth is, that a Government actuary should be appointed, to whom the Life Offices' accounts should be by law submitted, and who should have power to compel a safe course of action by the various Companies. Prior to the passing of the Act already alluded to, this last plan was, with various modifications, the one adopted in the American State previously mentioned.

We shall attempt to shew now the comparative advantages of each method.

First, as to the compulsory registration of accounts. In Mr. Cave's Bill, last year, many details were called for from the Companies—in fact, quite a sufficient number to enable any actuary who chose, to investigate for himself the affairs of every Life Office; but only to him would these voluminous schedules have been of

* See Appendix A.

any value. For any direct use these particulars could have been to the general public, they might as well not have been registered at all; and the sole benefit that could be derived by the community from their publication, would be the indirect one, that what is positively known to a few skilled persons, will in time penetrate the mass, so that an Office in a dangerous state *may* have its career closed at a somewhat earlier period than at present.

There is no certainty, however, that this knowledge will reach those immediately concerned, till the mischief is done,—and the reason is obvious. It is rather too much to expect of any body of men that they will subject themselves to the very doubtful chances of an action for libel, in a matter in which they have no personal concern. And by the time that, by private and privileged communications, the perilous position of any Office becomes known to a sufficient number of interested parties who will put in force the machinery the Act of Parliament may provide, rather than quietly make the best of their way out of the sinking ship,—by this time, we repeat, it is more than likely that the Company will be hopelessly involved.

There is a danger also on the other hand. The machinery proposed to be used in working Mr. Cave's Bill could be as readily employed to damage a good Society as to stop the career of a bad one. There was a clause in the Bill giving power in any Life Office to twenty policy-holders, representing £20,000 assured, to have a special investigation of its affairs made by the Board of Trade. Can it be doubted that, in such a time as we have just passed through, this power would be exercised without any better ground than blind fear? No arguments could convince, no statement satisfy, the policy-holder at such a season. He would consider himself certain of only two things,—the first, that he understood nothing of the matter,—the second, that he had a ready means at hand of getting those who did, to resolve his doubts. The temptation would, we think, be irresistible. And it is not alone people who honestly desired satisfaction that might put the clause in motion. Those who are popularly known as the wreckers of public Companies could not wish a better instrument to compass their ends. Even if the clause were not put in force, the threat to do so would be tried as a means of exacting compliance with the most absurd and unreasonable claims; and if the Office were really one that had something to conceal, the threat would be probably successful. Even as things are at present, attempts of this sort are *not unknown* in the history of Assurance; but, with a law giving

powers that could be turned to such mischievous account, the evil would become much greater. No such sword of Damocles ought to be kept dangling over the Assurance Companies, to be shaken down whenever panic-stricken ignorance, or hypocritical fraud, chose to do so. But, it may be said, the sword, if shaken down, would only be a terror to evil-doing Offices, but a praise and a help rather to those that did well. No doubt the vast majority of Life Companies would come triumphantly through the ordeal of a Board of Trade investigation; and as their soundness would have the Government mint mark impressed upon it, it might be supposed they would thrive the better thereafter. We do, however, believe this would be the case:—The provident classes, as a whole, seem to think of Assurance Offices as Cæsar did of Calphurnia. They ought to be above *suspicion* even; and if calumny, though proved to be such, were breathed against them, they would be more likely to divorce themselves from those Societies than join themselves to them. There would, in spite of everything, insinuate themselves fears as to whether there might not be some grounds for the petition after all; and rather than face these misgivings, people would prefer to insure in an Office on whose fair fame no doubts had yet been cast. And though the policy-holders of the Company which had safely passed through the fire could congratulate themselves on their tried security, they would soon find, in their diminished bonuses, that a petition for investigation was not, after all, a harmless affair.

Besides, even if no other injury were to result than the temporary check, is this anxiety to the policy-holders—an anxiety that would impel many to let their policies lapse, and thus in great part lose the fruits of their self-denial—is this deferring payment of the death-claims to those who may be in urgent need, of so little moment, that any knot of persons, whether it be through ignorance, or whether it be through fraud, are privileged to produce them?

And to obviate the difficulty, should any check be put on frivolous petitions, the danger is, that in doing so a barrier will be erected in the way of those who really have grounds for alarm, and a hindrance set to their obtaining either redress or explanation.

Without this clause, then, a Bill for registration of accounts is powerless—with it, is dangerous; and, whether with or without it, uncertain in its results.

A still further proof can be given of how little value to the general public would Mr. Cave's Bill have been, or indeed *any* Bill, which merely compels the publication of accounts, without appoint-

ing some skilled person to see that these accounts are satisfactory. *There is at the present moment more than one Life Assurance Company, transacting annually a large amount of new business, whose widely-spread pamphlets, though not exceptionally explicit, furnish to the actuary presumptive evidence of their condition sufficiently strong to make him carefully avoid the Offices issuing them.* It is possible that the statements contained in these documents are compatible with safety; but it is as possible that the reverse is the case; and it is certain that were the public aware of the construction that could be put on the facts there set forth, it would give itself, and not the Offices, the benefit of the doubt. And yet these Companies, with a confidence in the public that is certainly not abused by it, scatter these pamphlets broadcast, as the evidence of their undoubted security.

This seems to us final as to the benefit of such a Bill as Mr. Cave's. We understand the measure he intends to bring forward this session is to be similar in principle to that other. If it be so, though it cannot, should it pass into law, be entirely valueless, as it will enable actuaries to be absolutely certain in cases where they have only at present presumptive evidence, yet still it must fall very far short, both of the requirements of the public, or of what legislation might do in its behalf.

The second proposition—viz., The deposit in trust for the policy-holder with Government of a certain proportion of every Life Company's assets—next claims our attention.

What sum should be deposited? Obviously the only amount that can be logically insisted on is that which represents the liabilities, that is, the value of the policies. This involves, then, the fixing of a hard and definite line of valuation, and allows no freedom to the Offices at all in the matter. On this bed of Procrustes each Company would be tied down, and its reserve drawn out or lopped off, till the Governmental standard was reached.

A security supported by this means is not security, and is neither to be lauded nor desired.

That firmness and strength which is maintained by an enforced uniformity, not merely in vital but in minor matters, is not a thing to be wished, even in the interests of the policy-holder. In the diversity of practice among actuaries (a diversity, be it remarked, in no way affecting the Offices' solvency), there is benefit to the public. In the healthy freedom and clash of opinion, illustrated in practice, there is advancement to science, and gain to the world.

Besides, this hard-and-fast line has actually sometimes a tendency against security, inasmuch as it might, in consequence of an assump-

tion by it of a certain premium, which may or may not be the one received by the Companies, allow an Office to maintain a less reserve than it ought to have. The introduction to the New York Insurance Superintendent's Report for 1865 may be adduced in support of this statement.

These, though great, are not the only objections to the method of supervision we are now considering.

The rate of interest realized on Consols is little more than 3 per cent. An Insurance Company can readily, and without any danger to the principal, secure 4 per cent. Why compel the assurer to pay 1 per cent. as the price of a security that can be obtained without any such charge being made? He will very soon find, through the index of his bonus, that he is paying too dearly for his whistle.

That Consols are readily convertible, is no argument in their favour, but rather against them,—as to invest the mass of a Life Company's funds in a readily convertible security, is to needlessly sacrifice a legitimate advantage that Assurance Companies possess in the market, and which represents a safe increase in the interest obtained. A Life Office, though of course requiring a working balance, can afford to invest the bulk of its funds in securities that, though *safe*, are not rapidly convertible, as a "run" upon it is impossible. Even epidemics affect it but little. The cholera seasons which have occasionally swept over us have scarcely shaken the mortality experienced by the Companies.

Again, Consols are subject to fluctuations—not that there is in this any danger, if the margin retained be large enough; but as loans advanced on heritable securities, which form the bulk of most Life Offices' funds, are not fluctuating in value, they are, if this be an evil, superior as an investment. It must be remembered also, that where the Consols are bought outright, as this method supposes, there is no margin; but the market price at the time is the minimum one that must be obtained, or loss—small, no doubt, but possible—will result. As, too, this method, like all the others, requires the appointment of an official staff to see that the proper sum is invested and maintained, it possesses in this respect no special advantage over the others.

The third scheme is, that Government itself should extend its Assurance system beyond the industrial classes. This, it may be observed, in the first place, would be no help or remedy in the matter, as it would do nothing to benefit either those who are already assured in the private Life Offices, or those who might here-

after be so. It would simply furnish a refuge which might or which might not be taken advantage of. We have called it "a refuge;" but the better words would have been "a choice," as not even Government security is firmer than that of a well-conducted Life Office,—and of this class are the great majority of Companies. The resources of the latter are amply sufficient to meet all possible contingencies. Can more be said of the former?

If Government has no advantage in this point, in every other it is deficient; and so much so, that a Government Life Society never can be successful. The utter failure of the Industrial Assurance Scheme is a proof of this. The Post Office entered on that with far stronger points in its favour than it would have in a contest with the Life Offices. The Friendly Society system was, and is, pervaded with mismanagement and fraud to a degree which, not even in the unreasoning time immediately succeeding the "Albert" fall, did the most ignorant on the subject assert of Assurance Companies. The *one* argument of security told then with tenfold force. What has been the result? The swindling Societies are swindling still, and the same breakings up, and failures, and disappointments, are going on as before, with no perceptible diminution in the number of sufferers, while the Government ledgers are practically empty.*

Why should this be? Has the British artizan an insane desire to lose his money? Why should industrial assurers so obstinately prefer possible or even probable loss, to the absolute security offered by a paternal Government? Many good and sufficient reasons could be given; but the sum and substance of all of them is, that the official scheme does not meet their requirements. Nor can it! It never can possess the requisite pliability or adaptation to their wishes. Routine, to a certain extent, in so vast a machine as our national institutions, is indispensable; and even that amount of it which is absolutely requisite, would be fatal to all hopes of making the Industrial system a success, or extending it with advantage to ordinary Assurances. The truth may as well be told,—Life Assurance is too self-denying in its nature to cause any very large number to become partakers in its benefits, unless the matter is urged upon them by the personal exertions of agents, who themselves are continually stimulated from head-quarters. It is absurd to suppose that the tact and energy required to do this can be found in the slow and

* From the commencement, in 1865, up till the end of 1868, the number of policies issued under the Government scheme was less than 2,000.

lumbering movements that *necessarily* mark all departmental arrangements.

If, then, a Government Life Office would not succeed, and, whether successful or not, could do nothing to remedy any wrong that might be done those beyond its pale, we may dismiss it as unsuitable for our purpose.

There only remains the fourth suggestion,—viz., that a Government actuary should be appointed, to whom the Offices' accounts would be rendered, and who should have power to see that no Office stepped beyond the pale of solvency. And, lest it should be suspected that we are adopting the celebrated plan of stating that there are three courses open in the matter, and then proceeding to shew that one of them was absurd, the second impracticable, and the last utterly impossible, we may as well say at once that we believe in this last plan the solution of the problem will be found. The appointment of such an official—who, we may remark, ought to be unconnected with any Office—would give the check that is wanted,—and that, too, without raising the objections urged against the other plans, that they may cause the innocent to suffer as well as the guilty.

There are three objections that we have heard urged against this method of meeting the difficulty.

The first is, that a supervision by a public actuary might be considered as implying a Government guarantee of the solvency of the various Societies. No doubt this is possible with the ignorant; but we hold that, practically, no danger would arise from such a supposition, unfounded though it be. As with supervision, added to the natural safety-guard of what may be called the bonus-producing power of the Office, which will always, in case of need, come between it and bankruptcy; and the fact that, if requisite, the expenses could be reduced to the charges of a receiver to collect premiums and pay claims, we believe that the danger of a Life Company becoming insolvent is reduced to a chance so small as to render it unnecessary to take it into account.

The little value that the Registrarship of Friendly Societies has been, is no argument against the scheme we advocate. The number of Friendly Societies is so great that it is not possible to have them so thoroughly under control as the Assurance Companies.

The classes of the community which these Societies have to deal with are also more ignorant, and therefore are more readily imposed upon. And lastly, and above all, the office held by Mr.

Tidd Pratt failed to serve the end intended, because the statute creating it was merely permissive, and not compulsory in its provisions.

For these reasons no argument can be fairly brought against the plan now being examined, if it be drawn from the experience of the workings of the Friendly Societies Act, though it may be observed in passing, that this Act, and the office under it, might be, and ought to be, made really useful to the industrial community.

To object to Governmental oversight, on the ground that it may be mistaken for Governmental guarantee, and to offer instead of it a publication of accounts, stating at the same time that assurers must themselves judge whether these be satisfactory, is, for the sake of a very remote possibility, to put an obligation on the provident classes that they are quite incapable of fulfilling. It is to say that it is better that a general distrust should prevail of the Life Offices, and a consequent hindrance be put to the performance of the sacred duty of Life Assurance, rather than that by a general confidence there might happen the very unlikely thing that an Office bearing the Registrar's certificate became unable to meet the claims of its policy-holders.

This is no unfair statement of the case. It is quite certain the public will not comprehend these accounts. It will trust "all in all, or not at all." And, after the "Albert" catastrophe, should such a choice be thrust on it, the latter course is more likely to be followed than the former.

The second objection against this scheme is, that from the number of Assurance Company policies, any effective supervision will be impracticable. To this we reply, that in America a more rigid inspection than we advocate actually takes place. Valuations are there made by the State Insurance Superintendents, and made annually too. Far less than this will suffice. We do not consider it requisite for the Government actuary to value the liabilities and assets of the various Societies, unless in very special cases. An examination of the principles followed in determining this,—a subject treated of in the first part of our paper,—will, in most cases, be all that is necessary. What further may be requisite can be very readily done. A valuation to determine the exact amount of profit accrued, and a valuation to give an answer to the question, "Is the Society solvent?" are very different things.

This will, no doubt, be incapable of preventing swindling. That, however, is a thing which no system can efficiently guard against;

and the power of making a more rigid inspection, when thought necessary, would reduce this danger to a minimum.

The third argument that we have heard brought against this method is, that by it there might be unnecessary interference as to the details employed in valuation by the various Societies. If it be laid down that the sole duty of the Government actuary is to see that no Company became insolvent, we do not see how this can happen. Those who think so, must have in their minds the idea of a Life Office so near the boundary line of safety, that a very little matter will render it unable to meet its engagements. This is a state that no Life Assurance Society ought to be, or need be, in. For instance, say in the valuation of assets fluctuating in value—such as Stocks, or Consols—there is a good deal to be said, on the one hand, for valuing them at the immediate selling price, and on the other for estimating them as worth the average sum they would fetch in a series of years. The Government official might very possibly consider that the plan which put the less present value on them was the one that should be followed,—the actuary of the Society in question might hold the other opinion,—still, there would be no ground for interference in any well-conducted Office, as there would remain the reserve of the surplus loading, and the benefit in interest and mortality over the anticipated rates. These would certainly preponderate so much over the debated difference in value of assets, that even were the most rigid view of this point taken, the Office would be solvent. The same course would obtain in any other of the various questions of the debatable ground. Is the Office undeniably *solvent* when the most rigid construction is put on them? If so, there is no pretext or reason for interference. If in this vital matter the answer be doubtful, there need be no more words about liberty;—intervention is imperative, and is no hardship or injustice.

In this method, then, with the limitation, that so long as a Life Company was indubitably solvent there should be no interference, we believe the best solution of this much-vexed problem is to be found.

Whatever form legislation takes in the matter, there is one thing that ought not to be forgotten—the interests of the Assurance Companies are identical with those of the public. An Insurance Office really means those insured in it; for, in a Life Company, the stake of the shareholders—if shareholders there be—is a mere bagatelle to that of the policy-holders, and anything that will act

injuriously to the Offices will undoubtedly tell, through the bonuses, on the interests of assurers in them. How great that interest now is, few have any idea. In statistics which have been kindly put at my service by Mr. Thomson, of the "Standard" Company, the sum assured in the Life Offices of Great Britain is estimated, in 1869, as about £335,000,000; and the premiums payable under this sum, about £11,000,000 per annum.

Magnitude, however, is only comparative. In order, then, to understand how Life Assurance has pervaded the length and breadth of the country, let us compare its stature with that of another National Institution—Banking. Compare, say, the Scottish Banks and the Scottish Assurance Companies.

From Mr. Thomson's statistics, I gather that in 1869 about £62,000,000 represented the Scottish Banks' indebtedness and assets. The Scottish Insurance Companies had at the same date come under obligation to pay, and had assets present and prospective, to the extent of £85,000,000. It is true that in the Life Offices' assets, part is represented by the accumulated amount of premiums yet to be received. This, however, is legitimate enough; future premiums are "promises to pay," and it is the *responsibilities* of both institutions under present contracts that are being compared. If we take as our measuring-rod the notes in circulation of the Bank of England at 28th July last, the result would be still more striking,—the issued promises to pay of the Scottish Life Offices exceeding that of the issued promises to pay of the Bank by over £60,000,000.

While, then, so far as law can, it ought to be seen that the contracts representing these vast sums be discharged to the last farthing, it behoves, also, that this be done in the way that will work most beneficially to the policy-holder. We, with many others, believe that some such scheme as is here advocated is the best suited to this end; and that, were it adopted, the assurer would receive the one benefit more that is required to convert what is at present a moral certainty into an absolute one. A moral certainty now, inasmuch as, despite all that has been lately written by those ignorant of the subject, there is no one of our great Joint-stock enterprises in a sounder condition; an absolute certainty hereafter, inasmuch as, by like legislation to that we have indicated, the few doubtful Societies would disappear, and the host of reliable Companies be left a noble monument,—on the one part to the provident habits of a people, on the other to scientific research, to business capacity, and to commercial integrity.

Appendix A.

In a paper advocating legislation in connection with Assurance Companies, it is advisable to glance briefly at the various laws passed upon the subject in other countries, as well as the suggestions previously made in our own.

In 1853, the British House of Commons appointed a Committee on the question. The substance of their Report was, that the Joint-stock Companies Act was unfitted to meet the case of Insurance Societies,—that legislation on the subject should not be of a permissive, but compulsory nature,—that the Offices established prior to the Act of 1844 should come under the same regulations as those started since,—that in the case of projected Companies a certain amount of capital should be deposited with Government, not only as a guarantee of the *boná fides* of the undertakings, but also a security for their liabilities in the early stages of existence,—and lastly, that the Life Offices' accounts should be registered. It will be seen, from what we find afterwards, that a rule analogous to the fourth recommendation—viz., that a deposit should be made in the case of projected Companies—is in existence in almost every country in which there is legislation on the subject. The fifth, referring to the registration of accounts, is the first of the various methods we considered in our text, and the remarks then made will be applicable to it. On this Report no action whatever has been taken by Parliament; and the law, so far as it relates specially to Assurance Companies, is still in the same condition.

In Germany, prior to the war of 1866, each State had its own law, or no law, as the case might be, on the subject. Since then, the matter has again engaged the attention of the North Germanic Confederation, though no Act has yet been passed about it.

From a paper of Herr Hopf's, the manager of the "Gotha" Company in Germany, we gather that, in Austria in 1860, a decree was issued prescribing the manner in which the Life Assurance Companies' reserves were to be calculated, and commanding that a special fund, equal to this amount, was to be retained. A Commissioner was appointed by Government to see that this decree was complied with. This solution of the problem resembles the second of the methods we discussed in the paper, and is open to the objections there urged.

By a law passed recently in France, it is enacted that Life Assurance Companies are to be subject to the inspection and control of the Government. This decree is so indefinite, that it will sanction

any amount of interference, and allows each case to be dealt with specially on its own merits. This is, of course, in one way an advantage; but it leaves room for such abuses, that it is wholly inadmissible. It may be observed also that in France the promoters of Joint-stock Companies, before receiving authorization to commence business, have to shew the possession of a certain amount of guarantee capital, and the nature of the investments is also prescribed. The fourth safety-principle of our text is thus cared for, more than is necessary, we think. Except, however, the indefinite Act before referred to, there is no provision for the observance of the other three.

In Canada, a law was passed recently compelling Assurance Companies transacting business in the Dominion to make a deposit with Government of $100,000. This cannot be considered a satisfactory solution of the problem. In case of need, the guarantee asked for would not nearly suffice to discharge the liabilities of many Companies; and in the case of young Offices, or of Societies with a small amount assured there, the sum thus locked up would be greatly in excess of the worth of their obligations.

The United States' legislation on the subject resembles that of Germany before the war of 1866. Each State follows its own rules in the matter.

New York, prior to a measure passed last year, acted on the principle we advocate in this paper—viz., having a Government actuary to whom the Offices' accounts were rendered, and who had power to compel a safe course of action by them. We say the *principle* was the same, because various of the details were such as seem to us unnecessary and oppressive. As an illustration of this, we may point out that the Offices doing business in the State are compelled to submit an *annual* valuation of their liabilities to the Insurance Superintendent. An investigation so frequent is, we think, by no means requisite.

In 1867, an Act was passed, allowing Life Assurance Offices to make special deposits with the New York Insurance Superintendent of certain kinds of stocks or bonds; and thereupon the State Department, though not admitting any claim beyond the funds in its hands, undertook to issue for the Offices, acting in this manner, policies to any amount which would make the liability under these contracts, when calculated by the legal tables, not greater than the deposit. In fact, the law seemed to be of much the same nature as that regulation in this country, which, till lately, gave the herring curer the benefit of the Government brand. This Insurance Act allowed the Com-

panies the option of taking any number of these policies they chose to deposit funds for; but last year, New York State passed another measure compelling Life Companies, which had taken out *any* registered policies, to convert *all* their policies into registered ones,—thus lodging funds equal to their total liabilities, according to the Government tables. To the Offices affected by this law—and we think it will latterly be found impossible for any Society transacting business there to escape its meshes—there will be very little freedom of action left. In fact, the measure is practically the same as the second proposition condemned in our paper. Here, as in Massachusetts, where also a reserve, fixed by official tables, is compelled to be maintained, we hold there is over-legislation. The former regulations of New York State, we think, are much to be preferred.

The remaining most important features of this State's legislation on the question are the prohibition of Life Offices undertaking Fire or Marine Insurance, and the compulsory deposit by Companies commencing business there of $100,000.

We have now briefly glanced at what legislation has done in the matter amongst other peoples. It will be observed that almost all civilized countries have considered Life Assurance to be of so special a nature, as to have passed laws for its particular regulation and control. That this, too, has been done, not merely by nations such as France, where the Government is paternal, but also in such communities as the United States, where it is so very different. Strong evidence, we think, even had we not in the "Albert" fall a more pathetic proof, of the necessity of legislation in the matter.

APPENDIX B.

As the whole question of the solvency or insolvency of a Life Assurance Company turns on the amount reserved as the worth of the contracts, it may be well to furnish another view of the origin of the value of a policy, examining to what extent our rules can be directly applied to the expression for it.

We shall, on analysis, find that the formula is composite in character; so, before regarding it, we shall take up one of its elements—the premium.

The premium is the payment, periodical or otherwise, made by the assured in return for the obligation undertaken by the Company. Its composition may be set down as

$$p_x = \pi_x + \phi,$$

where p_x represents the payment made by the policy-holder, π_x the sum that is considered absolutely necessary to set aside to meet the claim, and ϕ the loading, or the addition made to this last amount, to provide for expenses of management, contingencies, and (in participating policies) to be the chief source of bonus. Now, generally speaking, though not necessarily so, the less the rate of interest assumed in calculating, the greater π_x becomes,—the reason being, that if we have to pay, say £1,000, thirty years hence, and arrange to meet it by banking a certain sum annually till then, if the Bank allow us a high rate of interest on our deposits, the yearly amount we should have to lodge would be less than if the rate were low, as the interest would help us more. π_x, then, is usually less when the Assurance Company calculates on receiving 4 per cent., than 3 per cent.

Let there, then, be two Life Offices, both charging the assurer the same premium—the one, however, assuming for the future that it will receive 4 per cent. on its investments, while the other says it will be safer to consider that only 3 per cent. will be made. Then, since in each case p_x is the same, and is equal to $\pi_x + \phi$—as, in the Company that values at 4 per cent., π'_x is less than in the one that values at 3 per cent.—ϕ, that is, the loading, must be greater in the former than the latter. If, in place of taking 4 per cent., the Office valued at 6 per cent.—a rate impossible of realization—π_x would then be very small, but ϕ would be correspondingly increased. Generally, then, the higher the rate of interest used in valuing the premium, the greater the loading; and the lower the rate, the less this margin will be.

We are now in a position to examine more particularly into the origin of the value of a policy.

If a number of persons band themselves together, and each pay into a common fund the premium that will be required to assure each, in say £100, for that year only, at the end of this time it will be found that the amount paid in will, with the year's interest on it, just suffice to discharge the death-claims. Let the same process be repeated at the beginning of next year, paying in this time the premium that would be required to assure each for £100 at his new age; at the end of the year all the funds, as before, will be required to meet the claims under the policies lapsed by death. Let the same thing be done till the death of the last survivor, and we shall find, as before, that at the end of every year the funds

in hand are just sufficient to discharge the death-claims arisen during the term; and at the beginning of every year there is a new start made.

This is the simplest form an Assurance Company can take. At the end of every year, after payment of the death-claims, there are no funds in hand, and no one's policy has any value. Acting on this principle, no Office could fail to meet its engagements. The year's income is the utmost sum that could be lost, even in fraudulent cases, and the elysium of Life Assurance would be reached at once. It is this scheme that is followed in what are called Yearly Friendly Societies,—the only difference being, that in place of fixing the sum that will be paid the representative of any member, should death occur, they fix the contribution to be made by each, and leave the other to be settled by the experienced rates of mortality and interest, and thus get rid of actuarial help altogether. We may remark, in passing, that we consider this the only kind of Friendly Society that artizans can safely attempt to conduct, unless they have occasional professional assistance.

Were it not for one thing, it would not be necessary, in either the Yearly Friendly Society or our imaginary Assurance Company, to have a fresh medical examination every time the new premium was paid. If no one left the Institution in any other way than by death, the claims would come in year after year precisely in accordance with our mortality table, even though, when the new contracts were entered into on account of certain members, they were at that moment on their death-beds. Unfortunately, however, death is not the only way in which members retire from Insurance Companies. They may drop their policies; and those who feel that they enjoy more than average health will do so, on much slighter occasion than those who doubt if they could again come safely through the ordeal of the medical examination they passed on first entering the Society. This result must then be guarded against by the Office. Were it not to do so, it would be left latterly with a pool of Bethesda-like collection of sick, and all manner of diseased.

This fear is neither imaginary nor exaggerated. At the present moment, in spite of all the advantages of medical examination in every fresh contract entered into, there are certain very significant facts in connection with assured life, that prove the effect of what may be called the selection of the public against the Life Offices. All researches have shewn that, in classes where a small immediate payment has been made for a given benefit, the death-rate is higher than in those where a high premium is paid. Thus, the mortality

is much more favourable among "with profit" than "without profit" policy-holders, and more favourable among these last than in those assured for a limited time. In short, the greater the premium paid for a fixed benefit, the less the death-rate, and vice versâ. The reason, of course, being that a person who feels that he is not in robust health, though quite strong enough to pass the medical examination, and even honestly answer all the questions that can be put to him, will choose that kind of policy which will give him the maximum sum assured for the minimum immediate payment.

The selection, then, of the public against the Offices is a most important matter, and one too little understood by the community. Not long since, we saw in a paper, professing to be a guide to the financier, a denunciation of Assurance Companies, as making immense profits by selling at mortality rates, in most instances taken from those of the general population, while they carefully selected their lives; and an appeal was made to the Companies to dispense with medical examinations. What a lazar-house and refuge for incurables an Assurance Office would become were *that* advice followed!

It would, then, in our imaginary Company, be necessary, at the time of making every new contract, to reject those whose lives had become uninsurable during the year. This would be striking at the very root of Life Insurance. It would fail those who trusted in it at the time they most needed its aid; as, in a large number of cases, nature would protract the struggle long enough to pass the fatal moment when the contract with the Institution expired, and could not be renewed.

This objection alone would be final; but, though the greatest, it is not the only one. As age drew on, the premiums by the yearly method would gradually increase, till, when they approximated to the sum assured, they would become intolerably large. For these reasons, among others, the plan of paying year after year the value of the current risk is unadvisable in practice, and it is to obviate these objections that the ordinary principle of paying by an equal annual premium was introduced.

It is obvious that in doing so, a greater payment will be made at entry than is required to meet the immediate charge. The difference between this current risk and the average rate paid is the value of the policy. Year after year, in consequence of the new payments of premium made by the policy-holder, and the accumulation at interest and mortality rates of the previously

received sums in excess, the value of his policy will increase, or, in other words, the reserve the Office has to make on his account will become greater.

By applying the foregoing principles, a formula for the value of a policy may be found. This view of the expression is commonly called retrospective, because it deals with the results of *past* payments made, in contradistinction to that taken in the text, which looks to the results of the *future*. By either method the resulting formula is of course the same.

Putting it in the form of an algebraic expression,—if x be the age at entry, and it be now n years from that date, the value of the life policy, or $V_{x|n}$, by either method, will be

$$A_{x+n} - p_x (1 + a_{x+n}) = V_{x|n}.$$

Where A_{x+n} represents the sum that now invested would meet the claim when it became payable, p_x is the premium paid, and a_{x+n} is the present value of an annuity of £1, payable from now till death. (Of course, a premium is just the same as an annuity, paid at the beginning of each year by the policy-holder.)

It will be remembered we previously gave p_x as equal to $\pi_x + \phi$. Substituting this, we have

$$\begin{array}{c} \qquad\qquad\text{DR.} \qquad\qquad\qquad \text{CR.} \\ V_{x|n} = A_{x+n} - (\pi_x + \phi)(1 + a_{x+n}); \text{ or} \end{array}$$

$$\begin{array}{c} \qquad\text{LIABILITY.} \qquad\qquad\qquad \text{ASSETS.} \\ V_{x|n} = A_{x+n} - \pi_x (1 + a_{x+n}) - \phi (1 + a_{x+n}). \end{array}$$

We put Dr. and Cr., or Liability and Assets, over different items of this, as the A_{x+n} is the present worth of the sum the Company will have to pay, and is consequently a liability, while $\pi_x (1 + a_{x+n})$ is a sum due to it by the assurer, and is consequently an asset.

Now, we saw that ϕ represented the loading, or addition made to the nett or pure premium; then $\phi (1 + a_{x+n})$ will be the total value of all future payments of this loading; in other words, the worth at the date of examination of the whole sum that is required to pay future working expenses, to provide against future contingencies, and to be the main source of future profits. Should, then, the Company consider this also a present asset, and without making any corresponding addition to the debit side, take credit for this amount, the foregoing formula will be the one employed in valuation; and the first of our rules will be completely disregarded.

If the loading be reserved intact, the formula used in valuing will become

$$\begin{array}{cc} \text{Dr.} & \text{Cr.} \\ A_{x+n} & -\ \pi_x (1 + a_{x+n}); \end{array}$$

or, what is the same thing,

$$\begin{array}{cc} \text{Dr.} & \text{Cr.} \\ A_{x+n} & -\ p_x (1 + a_{x+n}) \\ & +\ \phi (1 + a_{x+n}). \end{array}$$

The second principle insisted on was, that the rate of interest employed in calculating the values of the policies be not greater than that certain of being realized.

When we apply the rate of interest to our formula,—

$$\begin{array}{cc} \text{Dr.} & \text{Cr.} \\ A_{x+n} & -\ \pi_x (1 + a_{x+n}), \end{array}$$

we find that the less the interest, the greater A_{x+n} will be; but, unfortunately, the greater also a_{x+n}, and generally also π_x, so that, as both terms of the expression increase together, it does not appear necessarily true that the less the rate of interest assumed, the greater the value of the policy will be. Notwithstanding, it may be safely predicated that a valuation at 4 per cent. will always, in practice, give a less liability than one at 3 per cent.,—and, therefore, the latter is so far the more prudent of the two; we say "so far," because, recurring to the formula,—

$$A_{x+n} - \pi_x (1 + a_{x+n}) - \phi (1 + a_{x+n}),$$

we saw that if the interest rates be 4 per cent. and 3 per cent. respectively, in two Companies; at 4 per cent., $A_{x+n} - \pi_x (1 + a_{x+n})$ will be less than at 3 per cent.; but then ϕ, and, consequently, $\phi (1 + a_{x+n})$—or the loading reserved—will be greater in the 4 per cent. rate. This will somewhat compensate for the greater rate being chosen.

In talking hitherto of valuations by 3 per cent. or 4 per cent. interest, we have assumed that every element of the formula is taken at the same rate. This, however, is not necessarily the case, and the problem sometimes appears in the more complicated form in which, for a certain part of the expression, one rate is chosen, and for another part a different rate. Thus, it might be,—

$$\begin{array}{ccc} \text{Dr.} & & \text{Cr.} \\ 4\% & 3\% & 4\% \\ A_{x+n} & - & \pi_x (1 + a_{x+n}). \end{array}$$

In this case the candle is burnt at both ends; for, besides reducing the Dr. side by using a 4 per cent. interest rate, we at the same time increase the Cr. portion by taking the large 3 per cent. premium, instead of the smaller 4 per cent. one.

We do not, however, mean to assert that a composite method of valuation is always unsafe. That depends on the elements introduced. Whatever these may be, the principle laid down in the text will meet all the requirements of solvency.

The third principle referred to the deaths experienced as compared with those anticipated. Here, too, the formula yields us no assistance, as a table shewing a heavy mortality does not necessarily give a higher value for a policy provided for by periodical premiums than one shewing a lighter rate. It depends rather on the inclination of the death-rates to each other at the times of entry and examination. The rule will, however, guard against the effects of bad or no selection, as the case may be; and is, like the remaining element of safety, the worth of assets, more of a practical than theoretical nature.

These four things we consider, then, to lie at the root of the question of Life Assurance Companies' security. It is to them that legislation should be mainly directed; and should any Government actuary be appointed to carry out the decree of Imperial Parliament in the matter, it is the state of every Office on these points he will more particularly scrutinize and watch.

III.—*On Defects of House Construction in Glasgow as a Cause of Mortality.* By DR. W. T. GAIRDNER, Professor of Practice of Physic in the University of Glasgow, and Health Officer of the City.

Read before the Society, February 9, 1870.

DR. GAIRDNER, at the outset of his remarks, said, that all he had undertaken to do was, not to read what was generally known as a paper, but merely to make a statement which would form the basis of a discussion on sanitary subjects. Anything more elaborate he could not take upon himself to lay before the Society, at a period of the year when he was overwhelmed with other work. He then said:—

I beg to proceed to make some remarks upon defects of house construction, as they occur in Glasgow. We are all aware there has been a great deal of public attention bestowed upon this subject of late; and therefore it has occurred to me that, with the number of practical and at the same time scientific men who form this Society, it might be useful to put before you a statement or an argument tending to bring the question of house accommodation back, as it were, to its first principles,—to shew what is, and what is not, the central idea of a house, and how that central idea of a house has been in times past, and possibly is even now, violated in this great city of ours. I shall not make my remarks in the slightest degree personal. I have no wish, indeed, to bear hard upon anybody. I am quite aware that the faults that exist are faults which have been in great part transmitted down to us from our ancestors, and that the cure of them will be a matter of time, and will require a great amount of public energy and public thought. I think that hitherto there has not been, perhaps, a sufficiently widely drawn attention either to the extent of the evil or to the measures that are regarded as remedial measures. And speaking as the organ, as one may say, of the medical opinion, in so far as it has been called to it officially, I may say our difficulty has been all along the fear that our own position is not sufficiently secure,—the fear and the certainty, indeed, that we could not propose, with any chance of carrying public opinion with us, measures of the extremely strong and radical order that are absolutely necessary to cope with the immense evils we have to deal with. Till we have public opinion with us—and this is not only having the arm of the law, as represented by the authorities, with us, but the large concurring force of public opinion—till then, I believe, we shall be too weak to cope successfully with the evil; but I am not without hopes, from the great attention bestowed on the subject by newspaper editors and commissioners, by deputations from the Corporation to English towns, and from the various ways in which the attention of the public has been called to it—in a manner it never has been before—that the principles that lie at the bottom of the whole matter will now obtain a degree of consideration they have never hitherto had. Now, it is difficult to know where to begin,—the evils in our great towns are so many, the bearings of those evils are so intricate, the interweaving of the physical with the moral is so extremely complex. But perhaps we may begin at the fact of overcrowding,—a primary fact, one recognized in every investigation into the state of great towns, from the time of the first

inquiry by Lord Shaftesbury, then Lord Ashley, and Mr. Chadwick, about 1832 and 1834, down to the present time. We may take it as admitted that overcrowding is perhaps the greatest cause of disease in our great towns, and that it is also very intimately connected, in some way or other, with the social degradation and misery of a very large portion of our working classes. I will go further, and will say, that this state of matters is found in a very special degree in this country; whether from our insular position, necessarily, as it were, hemming in the population by the sea, or from the great tendency to an increase of the population, which is peculiarly characteristic of the English, Scotch, and Irish people—whether from either or from both of those causes combined, overcrowding is an evil of a character and dimensions in this country that it is in no other country, I believe, in Europe; and the great question that arises is, How far is overcrowding the cause and the effect of the evils referred to?

It may seem paradoxical, but, nevertheless, I believe it is perfectly true, to say that overcrowding is both the cause and effect of a large number of those evils. It is, in the first instance, the cause, because populations come from remote parts of the country, with perhaps very imperfect ideas of domestic comfort, and with a tendency, therefore, to overcrowding, and are subject to inducements to overcrowding which are greater than those existing in the country. But the evil does not stop with the first generation, because the second generation is brought up under a set of mental and moral impressions, and under a set of physical insensibilities, so to speak, which tend to make overcrowding a worse evil in the second generation than in the first. Whatever the original cause of these and other bad habits, you may take it for granted that they tend to impress themselves indelibly, after a time, on the whole nature, moral and physical, of entire generations of men. It may be said, without the slightest exaggeration, that there are scores of thousands of persons in this great city, who have been so brought up that they literally do not know, and literally cannot feel, the value of house-room—of more space in the house in which they dwell; and they cannot even rise to the idea of the most limited kind of domestic comfort. Nay, more; it is the case that they literally prefer discomfort—absolutely prefer overcrowding; they regard it in the light of a positive inconvenience to have more than one room for the family, because, they say, "What is the use of other two or three rooms? you would simply have your neighbours coming and sorning upon you." It would simply be an inducement to the less well-

housed to come in and eat up their family resources. Now, many evils result from this state of things; but I shall only mention four of the consequences of living in that condition of overcrowding and domestic discomfort. The first consequence is enormous liability to epidemic disease; and not only to epidemic disease, but to consumptive disease, and various diseases of the lungs; and, further, a literally enormous rate of mortality in young children in particular, partly, of course, from epidemic disease, but partly also from a great number of other diseases, especially nervous diseases, convulsions, hydrocephalus, tubercular diseases of the abdomen, and various other kinds of disease which we know to be destructive of infantile life. The second consequence is, that, from living in this state of habitual overcrowding, the sense of decency is injured inevitably, and ultimately it is lost altogether. The third consequence is, that almost inevitably a craving for alcoholic stimulants is generated; in many cases due, not merely to bad habits, not merely to bad examples, and not merely to the neighbourhood of spirit shops, but due to the want of what we may call natural stimulants, which go with us all to make up the idea of domestic comforts. Of course, I do not mean that there may not be persons who, by dint of superior virtue, are able to preserve themselves almost under any circumstances from these evils. It is the internal discomfort, it is the dreadful want of fresh air and of anything to relieve the monotony and dulness of life at home, that drives many to the public-house. Instead of regarding the public-house as the creator of the evil in the full sense, as some of our more extreme teetotalers do, I think the public-house arises where the demand exists, and where there are none of those natural stimulants which help to make home a desirable residence. The fourth consequence of this state of overcrowding, in badly-constructed houses, is, a great degree of moral degradation and of religious apathy. How should it be otherwise? How is it possible for the most elementary ideas of morals to be kept up, where husband and wife, and ever so many children of different sexes, or where husband and wife, one or two young women, and a male lodger, sleep in the same apartment? How is it possible that the ministrations of the minister of religion can be in any way effective in these circumstances? How is it possible that the highest and most refined transcendental idea, as it were, of human nature, should gain access to homes of the kind that I have now described? The thing is simply impossible. We therefore put down moral degradation and religious apathy as among the ultimate consequences of this evil. Now, I anticipate at this point a certain

objection to the views I am going to present. It will be said, "You have spoken of this as an evil of great towns; but has it not been proved over and over again, in the reports of the Sanitary Commissioners, that overcrowding is just as great and as rife in the most remote country districts as it is in the great towns? Is it not proved that the inhabitants of an Irish cabin in Galway, and of a Highland shieling in Lewis, are just as overcrowded, just as physically dirty, and their inhabitants physically living upon as low a scale of comfort, as the lower classes in great towns like Glasgow?" But, on the other hand, it may be said "that overcrowding is always and everywhere an evil." It is not in the same sense or degree an evil in the isolated hut or row of cottages as it is in the tenement of houses in a great city: for in the great city there are several conditions that do not exist in the isolated hut or shieling, let them be ever so overcrowded—let the physical outside of them be ever so poor, and the interior ever so squalid. In the *first* place, in the town there is the overcrowding of the ground as well as of the room. There is not merely the overcrowding of human beings in the room or house, but there is the overcrowding to an enormous extent of the number of rooms and houses upon a given space of ground. The consequence of this is, that there is literally no possibility of wholesome occupation, exercise, and amusement out-of-doors, in the neighbourhood of the homes. As to the most squalid Highland hut, there is the hill-side to go to; there is the neighbouring burn to carry away impurities; there is the grass meadow, the river side, the trout to catch in the burn for the children, and every sort of outdoor recreation, in the midst of fresh air. In the town there is nothing of the kind. The evil of overcrowding in the town, as regards facilities for recreation out-of-doors, is therefore enormously greater than it is in the country. *Secondly*, there is not merely overcrowding of the ground space with houses and with tenements, but there is overcrowding of the tenements with rooms, and of the rooms with persons. As there can be no true occupation, amusement, and healthful recreation out-of-doors, so there can be no time, day or night, when the family is safe from invasion, and when the instincts of home can possibly be cultivated, in the middle of those great collections of human beings, in tenements crowded upon a small space of ground. In both these particulars our cities, and especially our Scotch cities—perhaps Glasgow above all other cities—have erred in permitting such constructions as make it simply impossible to preserve the domestic habits; and this has been going on increasing in amount, from year

to year, for at least several generations. It is true that the habits of the immigrants into our great towns are often aboriginally bad, especially where, as in the case of Glasgow, many of them come from Highland shielings and from Irish cabins. But then the effect of these bad habits is intensified, and in most cases bad habits are meanwhile created, by the transference of these rural aborigines to the town habitations. Hence, from generation to generation, a progressive deterioration, and finally an almost total loss, of the instincts of the family.

Now, it is at this point that I approach, as it were, the theme of the present discourse. What I want to prove to you is, that, to a great extent, it is the house that makes, and the house that mars, the individual and social man,—not to say for a moment that individual character has not a great deal to do in the matter,—not to say that the pure-minded, noble-minded man, with heroism in the blood and bone of him, with physical instincts of the most exalted kind, will not preserve himself pure from contamination in the midst of all these evils. But, speaking of the average of men, I hold that such as is the house, such will be the man. If you persistently keep up dwelling-houses that are inconsistent on a large scale with domestic comfort, you not only allow to grow up in these houses, but to squat in them, generations of men whose ideas of domestic comfort will go on deteriorating every year. Consider how much is implied in what I have called "the domestic instincts." How many of the noblest virtues are embraced in that category! Is home not for every one of us the real school of all the virtues? Is it not true that home, and everything that grows round the home, is the real God-appointed school for virtue, religion, everything that raises humanity above the beasts? Well, then, you cannot consider a house as a mere mass of stone and lime. You cannot consider it as just four walls. You must consider it in the light of a home to bring up a family in. If you establish in your cities dens (I have called them over and over again "fever dens," but let us say, in the meantime, dens) that are not fit for the dwellings of men, you may depend upon it that the inhabitants will grow up with the habits of wild beasts. I assert, without fear of contradiction from anybody who knows the state of the case, that in most parts of Glasgow, and of other great cities in Scotland, a healthy and well-trained family is not even a possible thing, from the overcrowding of the ground on the one hand, and of the houses and tenements on the other. These evils are constantly being aggravated by the pressure of the rural population towards and

into the great towns, whereby larger and larger proportions of the population of the whole country are exposed to the deteriorating influences of homes in which it will be literally impossible to preserve even the traditions of healthy family life. Hence the rising death-rate, the increase of epidemic sickness, and deteriorating morals with respect specially to drunkenness, and of sexual immorality among the lowest classes in our great towns, at the very time—observe, I speak of the last fifty years—when the upper and middle classes have everywhere improved in their habits, and are less subject to the causes of mortality than they were half a century ago.

Here, then, is the problem you have to solve. When our middle and upper classes are rising in the scale, our lower classes are going down, and down, and down, and a larger number every year is pressing into our towns, to become part of the enormous mass of degraded humanity. Now, studying this subject from the simple point of view of sanitary reform, and dismissing for the time moral and religious considerations altogether—although I hold that the two cannot be separated—let us try to discover what is the minimum of house accommodation consistent with health, and, if you will, moral health; but moral health, not in respect to sin and crime, but merely in respect of the cultivation of the common instincts of humanity. I have discovered this minimum, by asking what is the minimum of requirements which can be reconciled with the healthy development of the individual family. I take the family as the unit of society. If you can render your houses such as will conduce to the healthy development of one family, you may depend upon it that society at large will not deteriorate; but if, on the other hand, you cannot do that, society must inevitably deteriorate. It is not too much to affirm that the following eight points are essentials in a house. The first is adequate cubic space in the apartment; by that, meaning, of course, the sleeping apartment. This was intended to be secured under the Glasgow Police Act; but every one knows it has been very imperfectly secured by the legal minimum of 300 cubic feet for every adult and every person above eight years in the family, and 150 cubic feet for every person below eight years. The minimum allowance of cubic feet is far too small for a healthy existence; but it was so put into the Police Act—and I do not say unwisely—under the impression that any higher requisition than this would simply be more likely to be disregarded. Even this limited allowance, however, is not properly enforced, partly owing to legal difficulties, and partly to the tenderness of

individual magistrates, who have felt, not unnaturally, when poor wretches were brought up to be fined for living in overcrowded houses, and pleaded in extenuation that they could not afford to get more house-room, reluctant to inflict a fine under such circumstances; yet the fining of the occupier has hitherto been considered the only way to meet the evil. Now, I think, this is beginning at the wrong end. The conviction has been growing in my mind from year to year, that the only way to prevent overcrowding is to throw the legal responsibility for it on the owners, and not on the occupier. It is the factor visiting the property from week to week, uplifting the rents, who can, if he pleases, prevent overcrowding. He knows perfectly well the class of people that crowd into these houses, and he can, with comparatively little hardship, make them feel it to be an essential requisite that they shall not continue the practice of overcrowding. I believe that the powers of the law would throw this responsibility upon owners and factors; but our Procurator-Fiscal doubts it. If, then, the powers of the law won't do it, let us get new powers, and devolve the responsibility upon the owners.

The second essential is the means of separation and privacy for the sexes within the houses. The first question that arises is, Whether separation and privacy for the sexes are possible under the condition of single apartment occupancies? That is a momentous question in Glasgow. I am not in a position to state positively—the next census will perhaps inform us—what is the number of single apartment occupancies in the city; but, from all I know, or have been able to discover, from my assistants and others, I believe that it is not much less than 35,000. At all events, it is between 30,000 and 35,000; or in other words, you may say that probably something like a third of the whole inhabitants of Glasgow are living at this rate of one family to a room, and in some instances lodgers are taken in besides. Now, taken in this large way, I suppose no person here will have the slightest difficulty in answering the question, Whether separation and privacy are compatible with a single occupancy? Certainly not on a large scale; and yet, I think, it would probably prove an unwise measure to proscribe single apartment occupancies altogether, because you must recollect that families are not always large. A young man and his wife begin housekeeping without children. They go on for a year or two, and, while the children are young, there may be no violation of propriety or domestic comfort in occupying a single apartment, which they do with much greater economy, and, if of prudent and saving habits, with a much greater power of saving up money for the future.

Then there is the case—and it requires peculiar tenderness—of widows and of old couples without children, or whose children have passed away or gone out into life. These are cases for single apartment occupancies; and therefore I should be very sorry indeed to see an iron rule applied, proscribing single apartment occupancies altogether. While, however, single apartments may be allowed to a certain limited extent, it is perfectly clear that tenements wholly or chiefly composed of single apartments are quite inadmissible in a well-regulated town, and ought to be put down without the slightest remorse. Yet, in Glasgow, the manufacture of single apartment occupancies, out of buildings originally constructed for houses of two or three apartments, has been going on for many years, unchecked by any process of law; while vast numbers of tenements, originally built otherwise, have been deliberately degraded, with a view to profit, into warrens of single apartments. In very few instances has a contrary process taken place—viz., the destruction or removal of such, to replace them by more healthily-constructed houses.

The third essential is a proper means of access. To judge by the tenements at present existing, one would say that proper means of access have literally been considered of no account at all by our Glasgow builders. The whole traditions of house architecture in Glasgow, the whole ideas of Glasgow builders, seem to me to have been based on the principle that the mode of access to rooms was not of the slightest consequence, provided people were able to smuggle themselves into them—in fact, that the cheapest mode, the cosiest mode, the darkest mode, and the dirtiest mode, was absolutely to be preferred. The usual plan of the Scotch common stair, even in the houses of the middle classes, has been all along essentially bad,—a receptacle for foul air, usually closed in at the top, and receiving the effluvia from all the houses on the stair, the lobbies of the individual houses being internal, and almost always unlit, except from the rooms, and therefore close, dark, and stifling, and the water-closets usually ventilating into, and being lighted from, the common stair. This is the plan of thousands of houses in Glasgow reputed fairly decent and wholesome, but which are simply a collection of sanitary abominations, and ought to be restrained and disallowed by law in newly-built houses. But when the same principle of internal lobbies or corridors, abutting upon or opening to many rooms, without separate ventilation and lighting, is carried into the tenement houses of the poor, and especially into houses of single apartments, all the evils above indicated, with the exception of the

water-closets, of which there are rarely any in such houses, are immensely exaggerated in effect, and the facilities for the communication of infectious disease are correspondingly increased. Yet such is the construction of tenement houses. Until within the last two or three years, no builder ever thought of constructing a tenement house in Glasgow upon any other plan. The sanitary evils have been increased to the very utmost in many cases by the accumulation of numbers of ill-ventilated and overcrowded single apartments, with corridors wholly devoid of separate lighting and ventilation, and with internal closed common stairs, so that the whole tenement is pervaded by an atmosphere common to all the houses, and literally loaded with the germs of disease. This is the leading and all but universal error of house building in all the Scotch towns; and until it is thoroughly and systematically corrected, there cannot be a moderately healthy population. I may remark that, about seven years ago, in a course of lectures I delivered in Edinburgh upon public health, and which were afterwards collected into a volume, now out of print, I commented upon the fact, that while in certain marked instances the English towns were lowering in their death-rate, the Scotch towns were almost universally increasing in their death-rate, and connected that fact in my own mind with this feature of Scotch house construction, which does not prevail in England at all, where almost invariably a tenement is technically called the house of an individual man, and there is some individual person responsible for it; whereas in Scotland no one is responsible but the factor. The question has been raised by a zealous and energetic gentleman, whether some good might not be done by causing, or enforcing by law, that in each of those great tenement houses there should be some resident tenant, who should act as a kind of *concierge* or porter and preserver of the peace and cleanliness of the whole. The Scotch system of building you may consider as a draft from the Continent. It was owing, I believe, to our greater intercourse with France that this system came in, as opposed to the English one; but then you observe, in the Continental system, the building always has its *concierge*, who is responsible for the keeping of the whole; whereas our Scotch common stair is just simply a mass of chaos and confusion, with no one to keep order.

The fourth essential of a house, in my opinion—keeping in view a family as the occupants of the house—is proper lighting and ventilation of rooms, as well as of lobbies. The mere structure of Scotch houses leads to the neglect of that; and neglect caused by mere

structure has not been removed by ordinary means of ventilation; but in newly-constructed houses, I believe it is quite possible, as has been done in London, to introduce a shaft between the walls of the building and the chimneys, giving rise to a ventilating current that would draw off from the rooms; and even in old houses in the city I have seen considerable improvements effected, consequent on a simple expedient,—one introduced by Mr. Hoey, father of the secretary of the section of Sanitary and Economical Science; and I have no doubt that even our old houses could be improved by careful and diligent consideration applied to this matter. But, besides, the windows have often been too small, or have not been made to open, or have been built up by walls interfering with the circulation of air. Box-beds or dark closets have been used as sleeping apartments, and underground dwellings still exist which ought to be shut up.

A fifth essential is adequate privy accommodation. I regard this as a first necessity of healthy domestic life in a town. No habitation can be considered admissible in towns where accommodation of this kind is not provided, so as to be easily accessible to women and children, as well as to men; and so far brought into connection with individual tenancies as to secure real privacy, as well as the responsibility of individual householders for cleanliness and the prevention of nuisance. It is scarcely necessary to point out that, in this particular, our Glasgow houses, even of the respectable working classes, have often been systematically deficient; and in the tenement houses of the lower working classes, it seems as if the very idea of privy accommodation had been deliberately abandoned. We know, in fact, that in a past generation the midden heap in the open court was often the only form of deposit for filth, contemplated by the builders of houses intended to lodge hundreds of human beings; and in very many instances the ground has been so occupied, and the structure of the houses has been so complicated, that neither without nor within the house has it been found possible to supply the deficiency. The system of public privies is no doubt an advance on this absolute want; and you have only to look to the reports of Dr. Neill Arnot and Albert Smith, to see that the absolute want of privies was the rule thirty or forty years ago. But the system of public privies does not properly supply the want; indeed, a public privy is a contradiction in terms, and is quite inconsistent with a due regard to the cultivation of the domestic habits. I do not here enter on the disputed questions, how far water-carriage, on the one hand, or other systems of removal, on the other, are the

preferable modes of disposing of excrementary filth; the one point needful to be maintained at present is, that the privy should be really what its name implies, and not, as it is throughout the poorer quarters of our Scotch towns, a common resort of the men in all the families of a populous tenement, while women and children almost invariably refuse to go to it. But how this improvement is ever to be accomplished, except by a complete change in the views of builders, or of the authorities controlling builders, as to what are the domestic essentials of such tenements, I confess I cannot see. In houses constructed for the poor, we are in this dilemma: to admit the water-closet, or any other form of privy, into the interior of the house, is simply to court the diffusion of unwholesome gases; while to rule in favour of accommodation outside of the house, is to sacrifice the whole idea of decent retirement, and make the privy a place for the deposit of the miscellaneous filth of a whole village of persons, many of whom are already lost to all self-respect, and perfectly careless both of their own comfort and of that of others.

The sixth essential of a house is an adequate water supply. Upon this subject I shall say little, because, by the aid of the Water Commissioners, Glasgow has now been supplied with water almost as effectually as the existing nature of the houses admits. But here, too, the construction of these tenement houses has stood in the way of the supply of water. In the house represented by one of the diagrams before you, there was no water supply until quite lately; and although it is a house of sixty or seventy families, there is no water except in the close. The reason was, that the whole interior of the lobbies was so utterly dark, that to put a water supply in any lobby or landing would simply be to keep the place in a perpetual state of slop and puddle; while, on the other hand, to put water in the rooms, would bring in the objectionable principle of having water-sinks, and therefore the possibility of regurgitation of gases in single apartments and bed-rooms. Hence we were obliged to decide that no water supply should go into that house of six storeys high until it was remodelled.

The seventh essential of a house is baths and wash-houses. Upon this point I shall also say very little, because the propriety of the thing is almost universally recognized, and it is only owing to adventitious circumstances that efforts have not been made by authority to supply the want hitherto. But it will require careful consideration even now, not only on what principle a public bath is to be managed, but also on what principle you are to supply wash-houses to the inhabitants of these enormous tenement houses. As

a rule, these people do not like to go to public wash-houses at a distance. They much prefer to wash in their own apartments; and if you want to seduce them out of that habit, and thus give them facility for washing upon a larger scale, you must have wash-houses placed in such proximity to the rooms, that one wash-house is only used by a limited number of persons. That is nearly impossible in the old tenement houses of Glasgow. Here, again, therefore, we find the same difficulty, the construction of the houses having been such as not only not to supply the first wants of domestic life, but to make it impossible, by any subsequent attention to details, to supply those wanting elements in anything like a reasonable and useful form.

The eighth and last particular I shall touch upon as essential to a house, is airing and recreation ground. Now, perhaps even some persons here will be inclined to say, "Oh! this is quite an extravagant view of the subject. Have we not good broad streets? Airing and recreation grounds are not always attached to the houses of the better classes,—why have them for the poor? This is an altogether Utopian idea!" Well, I say, from the very fact of placing this among the essentials of a house, it will appear that a verdict of condemnation is passed upon the entire system of multiple occupancies within vast tenements, such as exist in Glasgow and most of the other large towns in Scotland. Yet the verdict is not too severe, where it can be proved that over considerable areas 600 to nearly 1,000 persons—men, women, and children—live together, in what are supposed to be families, upon a statute acre of surface. What kind of family life, it may be asked, is even possible under such circumstances, where the children have literally no place to meet each other, except in these dark lobbies of the houses? or, if they go out of them, no place whatever, except the middle of the street, and this in parts of the town where thousands and tens of thousands of families are brought together, and where there is literally no street that is not a crowded thoroughfare; where the houses have no back yards, and where, excepting the street and the close, and the nasty, stinking, dirty lobbies, there is literally no place for children to play, or in which old people can take a little exercise.

Dr. Gairdner, after reading some extracts from the first Report which he had published, as sanitary officer, in 1866, pointing out the evils to which he had been referring, concluded by directing attention to plans which he had got prepared in order to shew the nature of those defects in house construction which had formed the subject of his discourse.

February 23, 1870.—The evening was devoted to the discussion of Dr. Gairdner's communication, "On Defects of House Construction in Glasgow as a Cause of Mortality." The following is a *résumé* of the discussion:—

MR. DAVID G. HOEY read an elaborate paper on the subject of Dr. Gairdner's discourse. He asked whether he would be deemed guilty of exaggeration, if he asserted that the rooms in the West End terraces and crescents were, so far as the principle of construction was concerned, as faulty in respect of ventilation as the single apartments of the East End and central district—although, as a matter of course, the evil results of this grave error in principle were seen in their full enormity only under the severe strain of the densely-packed population in the latter quarters? What was the law which regulated the motion of air, when not acted upon by an external force? Simply this. Given, a chamber containing warmer and consequently rarer air, and another containing colder and consequently denser air: and given, a means of communication opened up between the two,—the current would immediately set in from the colder and more dense to the warmer and more rare. Now, as the case in point was that of the Scotch open entry and common stair, wherein the air was necessarily colder than in the interior of the house, it followed that the ventilation was not from the closet to the stair, but from the stair into the closet. He maintained it was just as impossible for the ventilation to be into the stair, as for water to run up hill. Just as the ocean was the ultimate goal of water seeking its level, so the fire was the ultimate goal of every breath of air that entered the house from anywhere without, seeking its level—viz., the spot where air of the least density was to be found. If, therefore—and this was his whole case as regarded ventilation—if they could so arrange (1.) that the admission of fresh air should be throughout house, lobbies, &c., continuously and smoothly flowing, not in gusts or draughts; (2.) that no hindrances should be interposed in its gentle unceasing progress through the lobbies and house to the fire; and, (3.) that the exit of foul air should be everywhere regular, thorough, and from a sufficiently high level,—then, and not till then, would they have anything worthy the name of thorough ventilation. Mr. Hoey also shewed how that Dr. Gairdner's essentials of a properly-constructed house were provided for in his (Mr. Hoey's) plans for working men's houses, and concluded by saying, that the cost of such tenements had been ascertained by application to a practical builder, and after including the feu-duty payable for the ground, and calculating the building at twelve years' purchase, he found that the smaller

houses could be let at £3 and £3, 5*s.*, accommodating each four adults, with two separate sleeping-places; and the larger at £3, 15*s.* to £5, 10*s.*, accommodating each six adults, or the equivalent in adults and children, with three separate sleeping-places.

Councillor Ure, who was called on by the President, said that Mr. Hoey had introduced his name in the paper read, and had repeated the opinion which he had given at the Police Board in favour of the system of ventilation which had been so well advocated that evening. Along with Dr. Gairdner and Mr. Carrick, he was taken to the places where that method of ventilation was in operation. They were two small houses—one of which, previous to the improvement being introduced, was so smoky that the people threatened to leave. The proprietor had been induced by Mr. Hoey's father to introduce this method of heating and ventilation; and the result was, that the smoking ceased, and the people, instead of leaving, would have preferred to have paid a higher rent rather than have done so. The other house, which was in the same land, was one in which a great deal of ill-health had prevailed; and, with the view to try the effect of it for the purpose of health, another of these grates was introduced, and the consequence was that the woman residing there admitted to Dr. Gairdner and those accompanying him that, from the time of its introduction till that of their visit, the inmates had enjoyed such health as they never had done before. They were unable to account for it in any other way than that the air in the apartment was fresh and pure. Having such testimony, he felt warranted in speaking in favour of the apparatus, and asking the Improvement Commissioners to introduce it into a building which he confessed he thought they never should have had, but which, with the introduction of this, must be made more healthy than single dwellings such as were in other parts of the city. It had not been so long introduced as that a strong argument could be based on it; but he understood the tenants were very well pleased with it, and possibly were disinclined to go back to the old system of open fireplaces. He was a firm believer in the possibility of making our homes more healthy than they were; and the method Mr. Hoey had brought before them was one which, if more generally introduced, would be found to assist in lessening the death-rate of our city.

Dr. Gairdner remarked, that the two rooms referred to by Mr. Ure were in one of the closely-packed houses in Lyon Street, and were not selected by Mr. Hoey, but by him (Dr.

Gairdner), for the purpose of being given to Mr. Hoey, on the ground that if they were bad, and as the proprietors were apparently anxious to see an improvement, the people were of such a character that they would put a reasonable construction on anything that was done.

Mr. Finlay said, it was the duty of every householder to look after his own ventilation, and if he did not learn the subject a little, and become even practically acquainted with it, he need not expect proper house ventilation. Proper ventilation was a fact of more importance to the individual than his wine-cellar.

Mr. M'Intosh thought that that portion of Mr. Hoey's paper was greatly to the point which had reference to the building of houses of a rental of from £3, 15*s*. per annum. Although he (Mr. M'Intosh) was averse to the Corporation becoming the owners or builders of houses, yet he thought it was within the province of the sanitary portion of the Corporation to build a block of houses on some such plan as that which had been described by Mr. Hoey. There might also be built two or three blocks upon other plans; so that if it could be shewn to the capitalists of Glasgow, or bodies of gentlemen who choose to invest money for the benefit of the working classes, that comfortable houses for that section of the population could be built at rents from £3 to £5, 10*s*., the problem was solved, more particularly as the calculations of Mr. Hoey informed them that he took the ground at 15*s*. the square yard. It was very well known that, within a radius of two miles of the cross of Glasgow, plenty of good ground could yet be got at the rate of 15*s*. per square yard, or a little more. He thought that was the true problem to be solved with reference to the overcrowding of Glasgow; for the working men were not such fools as to remain in close, ill-ventilated houses, with dark closes, dark stairs, and dark passages, if, at a moderate distance from the various centres of their work, they could obtain such houses as had been described by Mr. Hoey, and at the moderate rents which he had indicated. He (Mr. M'Intosh) had very considerable experience of the lower class of the working people of Glasgow, both in seeing them at their work and in their dwellings, and he was afraid that any scheme of ventilation, which depended upon an opening being made in outer passages communicating with the fireplace, would not meet with great approval from the female inmates; for they would say "there was a nasty, cold draught," and would immediately set about sticking rags into the aperture.

Mr. John Ramsay, of Kildalton, said that he had been much

interested in listening to the paper read by Mr. Hoey. He differed rather from Mr. M'Intosh, when he said that it had no bearing on the question of overcrowding, as it had a very important bearing on the question of securing efficient ventilation, which was one requiring to be solved in order to their ceasing their discussions about overcrowding. He believed it was an important consideration to those who thought upon the necessity of having separate apartments, and that no family should live in one apartment, that the district of Scotland which, according to the Registrar-General's returns, had the lowest death-rate, was the district in which there was the greatest number of families living in houses of one apartment. The insular districts of Scotland were distinguished above all other parts of Scotland by a low death-rate. He believed that in these districts the number of families living in houses of one apartment was greater than in any other district, in proportion to the amount of the population; and he believed this was secured, as Mr. Hoey had said, not certainly by the superior nature of the dwellings, but from the fact that efficient ventilation was established, and that the people breathe fresh air. He believed that had an important influence on the health of the population, not only where there was the advantage of the sea breeze, but indoors, where the defective character of their dwellings might be such as not to secure that the inmates had fresh air to fill their lungs at each inspiration. He thought that if, in even the crowded parts of this large city, there could be secured efficient ventilation of the dwellings of the poorer classes, it would be a great boon to them indeed, and, he believed, would tend largely to bring about a decrease in the death-rate of the population.

Mr. Bromhead.—With regard to overcrowding, there was, he thought, an idea lost sight of by some of those gentlemen who had spoken about breathing spaces. It was quite true that a certain amount of air was required to breathe; but was it the most advisable way to attain so desirable an object, that the street in which dwellings were erected should be 60 feet wide? In England, and in Bristol particularly, it was extremely common to build workmen's houses of only two storeys, with the street only 30 feet wide. He thought that was preferable to the plan of having tall houses in wider streets, because so great a number of persons were not resident upon a given acre of ground, and because builders could afford to erect the houses in a better way. If a row of houses built upon the English style, usually in streets 20 or 30 feet wide, were erected in streets 60 feet wide, it would be abso-

lutely necessary, from the additional cost of the ground to be acquired, to increase considerably the rental of the houses. As to the water-closets, he would have desired to have heard Dr. Gairdner say a little more in his own peculiar province—he would have liked he had informed them whether there was any distinct injury to health in the mere fact of having no water-closets at all. He thought that designs for working men's houses were defective which did not provide a large amount of accommodation in the shape of water-closets. Since Dr. Gairdner had delivered his paper, he (Mr. Bromhead) had taken the trouble to examine seven tenements which had been recently erected in the western part of the city. They were seven tenements of dwellings, each dwelling with a water-closet in the centre of the building. The plans for these houses must necessarily have gone before the Dean of Guild Court, and must have obtained its sanction within twelve months. He did not think there was any apology for this; for exactly opposite the said tenements there were erected in 1861 buildings with the water-closets placed at the back, each water-closet and bath-room being 3 feet wide and 7 feet high.

IV.—*A Glance at some of the Vital and Social Statistics of Glasgow in* 1869. By Mr. William West Watson, F.S.S., City Chamberlain.

Read before the Society, March 9, 1870.

The year 1869 has been in this district characterized by an unusual amount of atmospheric disturbance, an unusual range of temperature, and, unhappily, by an extent of mortality unprecedented for many years within the city of Glasgow.

The year opened with unseasonable mildness—both January and February exhibiting the highest mean temperature of these months during any of the last ten years, with the exception of February in the immediately preceding year. There was likewise in these two months an unusual amount of rainfall, extending to more than one-fourth of that of the whole year; together with an excessive amount of southerly wind, and a very high rate of mortality. The succeeding month of March was characterized by the opposite

meteorological features; the temperature was lower than during the average of many years; the wind blew from the north and east during twenty-three days, in place of from the west, as is usual in this month; and the rainfall was the lightest of any during the entire year: in short, it was a bitter and inclement month, and the mortality of the city culminated in an aggregate of 1,768,—by very much the highest amount of any month upon record since the establishment of the registration system in 1855. Then followed April, equally unseasonable, but in an opposite direction,—it was the warmest April since 1856, with an exceedingly light rainfall, and an excess of southerly and westerly winds; and the mortality fell nearly 300 below that of March. Again, as if to vindicate the contrasting features of the seasons, May presented the lowest temperature and the lightest rainfall of any May upon record, together with an unusual preponderance of east wind; yet the death-rate shewed a diminution of nearly 100 as compared with April. The month of June exhibited a lower temperature than usual, up till the middle of the month, when a storm of great violence seemed to have brought the elemental derangements into something of equilibrium, —the remainder of the month was genial and seasonable, and the vagaries of the atmosphere subsided until (with the exception of September) nearly the close of the year, although August was exceptionally noticeable by an unusually wide range of temperature as well as by a deficiency of rain. The mortality fell to 1,013 in August; and, although September was marked by much atmospheric disturbance, indeed storms, and by a very unusual amount of rainfall, the mortality fell away to 915,—by very much the lowest of the year. October and November were average months, exhibiting no unusual features, excepting the frequency of high winds, with a very great preponderance from the west, and an unusual rainfall in the latter month; but the mortality made a sudden bound from 980 in October to 1,313 in November; and December closed this year of strange variations with the lowest average temperature of any December since 1860, a succession of stormy winds, a rainfall much above the average, and a mortality of 1,540,—being next to March, by far the most fatal month of this year. Bronchitis was, in both instances, the chief destroyer; this single disease, or class of disease, having carried off no fewer than 361 victims in March, and 409 in December. The aggregate of the mortality of the year assigned to this one cause furnishes a sad record of 2,545 victims, to which number no other disease in the catalogue, not even typhus, offers an approach of one-half, excepting

consumption [illegible] prove [illegible] the victims of [illegible] and phthisis. The majority of the [illegible] were [illegible] [illegible] [illegible] [illegible] under [illegible] years of age [illegible] numbered only [illegible] [illegible] the usual preponderance of male deaths from the former and of female from the latter disease is not very marked in the present instance.

With reference to these statistics of the two diseases in question, I have [illegible] to the [illegible] but in the meantime [illegible] that it has occasionally happened that acute affections of the respiratory organs are confounded with each other, and even sometimes with phthisis when assigned as the primary cause. [illegible] the same source of error continues from year to year and renders the registration of the causes of death as entered in the Registrars' book a means of comparing one year's results with those of another.

The year will also be long remembered in the West of Scotland for the remarkable drought experienced during the half year extending from the middle of March to the middle of September. Upon an average of the last ten years the rainfall during the six months in question has been as nearly as may be 1[illegible] inches, but in 18[illegible] it did not amount to 1[illegible] inches. Indeed, March, May, and August all combined contributed little more than one-fourth of even this small quantity. Now when we reflect that the period under consideration is that during which evaporation is most active, and also that it followed a year during portions of which a remarkably high and exhausting temperature was experienced, it is not surprising to find that the sources of supply in many places entirely failed. Indeed, but for the bountiful supply secured to us from Loch Katrine through the wisdom and forethought of the men of the present generation, Glasgow would undoubtedly have furnished a still more sad catalogue of mortality than ever it has previously done; and when we regard the condition to which some of the towns in our neighbourhood were reduced through the want of this prime necessary of existence—when the factories of Greenock and Paisley were actually brought to a standstill for a considerable period—the very vision of the extremities to which our enormous population would have been reduced becomes appalling.

The average rainfall at Glasgow during the last ten years has amounted to 44·535 inches, while that of 1869, taken alone, has

only amounted to 39·07 inches, that of 1868 having been 47·80 inches.

There were 15,640 deaths and 18,490 births registered during the year,—thus adding to the population, by what is termed "natural increase," only the small number of 2,850 souls. This is by much the smallest increase of this kind exhibited during any of the last nine years, the mere average of which has been 4,527, ranging from 5,778 in 1867, which was a year of remarkably reduced mortality, down to the 2,850 already named. The reduction is attributable partly to a diminution of the number of births, even as compared with 1868; but chiefly to the very marked increase in the amount of mortality, which, in 1869, exceeds that of 1868 by so many as 1,815, or 151 in each month. The following table exhibits the annual increase during each of the last nine years, as well as the averages of each of the events, and of the annual increase during the whole period.

NATURAL INCREASE OF THE POPULATION, 1861 TO 1869.

Year.	Births.	Deaths.	Natural Increase.
1861,	16,536	10,932	5,604
1862,	16,397	11,569	4,828
1863,	16,988	13,327	3,661
1864,	17,434	13,674	3,760
1865,	17,928	13,912	4,016
1866,	18,287	12,826	5,461
1867,	18,356	12,578	5,778
1868,	18,609	13,825	4,784
1869,	18,490	15,640	2,850
Total of nine years,	159,025	118,283	40,742
Average of years,	17,669	13,143	4,527

In a progressive population like ours, it is natural to expect that the mortality should likewise exhibit an increase; and if it did advance in any regular or even approximately-defined ratio, the subject could attract little or no remark; but it is not found to be so. The population advances sometimes with greater, sometimes with smaller strides; but the amount of mortality leaps and stops, advances and recedes, in the most fantastic fashion. As already stated, that of 1869 has amounted to 15,640; yet this enormous aggregate was exceeded so far back as 1847, when

upwards of 18,000 of our people died; and again in 1854, when 17,000 died; and was almost equalled in 1853, when nearly 15,000 died. But in each of these instances we can lay the finger upon a leading cause. In the first of these years it arose from famine and its consequences; in the other two, from cholera.

The year just passed, however, has not been rendered remarkable by any particular epidemic, but rather by a general aggravation of many of the diseases to which our population is exposed,—and among them are especially noticeable those connected with the chest. Foremost of all stands bronchitis, which carried off, as already stated, no fewer than 2,545 victims, shewing an increase upon the preceding year of 630, and exceeding by upwards of 700 the annual average of the last nine years. The increase of this sad malady presents some very singular features. From 1861 to 1865 it ran a tolerably equal race with phthisis, sometimes the one and sometimes the other preponderating; but since 1865 it has steadily widened the distance from its terrible rival. In 1865 it had a majority of only 8; but in 1866 this had risen to 119, and was followed by a majority of 244 in 1867, by 120 in 1868, and by 723 in 1869. Now, this is the more remarkable, because we are almost universally under the impression that phthisis or consumption is not only our deadliest malady, but is always rapidly advancing. I find, nevertheless, that while the deaths of 1869 from phthisis amount to 1,812, they do not very greatly exceed the annual average of nine years, which has been 1,716. Going back, however, sixteen or eighteen years, I find the following noteworthy facts upon record: that the deaths in Glasgow were, in 1852, 1,980 from phthisis, and 433 from bronchitis; in 1853, 2,490 from phthisis, and 513 from bronchitis; in 1854, 2,350 from phthisis, and only 394 from bronchitis.

It may possibly be objected to these last figures that they are open to doubt, being in a great measure derived from the loose nomenclature popularly applied to diseases, and so quoted to the burial registrar; but when we come to the succeeding year, 1855, when the Registration Act was in full operation in Scotland, and the returns were checked by the medical officials, we find a fair amount of corroboration of the approximate accuracy of the figures, for the numbers brought out for that year were 1,417 from phthisis, and 694 from bronchitis. A comparison of these figures with those of 1869—when 1,417 have advanced in fourteen years to 1,812, while 694 have in the same period assumed the magnitude of 2,545 —leaves little or no doubt as to the increasing fatality of bronchitis.

Before leaving this particular disease, or possibly class of diseases, let me advert to the fact that inflammatory diseases of the respiratory organs, in which bronchitis takes by far the leading place, are stated by the Registrar-General to be the only class that produces constantly twice the mortality in urban that they do in rural districts; for from 1855 to 1864 (the latest tabulated decennary), in every 100,000 persons who died in Scotland, there fell through these causes 150 in the insular, 204 in the mainland rural, while 407 were the victims in the town districts. As illustrative of the prevalence of this disease during last year in districts far remote from this, I instance the case of Whitechapel Union, a district of London somewhat analogous in character to our High Street and Bridgegate. It contains a population of about 70,000, or somewhere about that of the city of Aberdeen, and is situated in the very heart of the metropolis. Having been furnished with the returns, I find that while the pauper cases of bronchitis and catarrh—for they are there grouped together—treated by the officers of the Union, amounted, during the whole nine years preceding 1869, to 5,907, thus exhibiting an average of 656 a year, and while those of 1868 taken by itself had only amounted to 450, the cases of 1869 alone actually reached the enormous amount of 6,320, or considerably beyond the entire aggregate of the whole previous nine years. At the same time, I may mention, in passing, that with an experience something like our own, small-pox, which had averaged for the whole ten years, 1860 to 1869, 124 cases per annum, had dwindled in 1869 to 5 cases in all.

Typhus has taken off 948 victims, and exhibits a considerable increase upon the average of nine years, which has been 708, ranging from 1,177 in 1865 down to 338 in 1868. With the exception of the first two months of the year, and September and October, this disease has maintained a remarkable uniformity in its fatality; and, with the exception of phthisis, is by far the most fatal disease to our population in middle life. Of the 948, only 59 were under five years of age; 132 were of ages from five to twenty; 69 again were above sixty; while 688 fell in the prime of maturity, at ages ranging from twenty to sixty.

Thus, these three diseases alone account for 5,305 deaths, or more than a third of the whole mortality. Hooping-cough and scarlatina both exhibit a slight decrease, as compared with 1868, although both are greatly beyond the average of nine years. Pneumonia shews a large increase, and is also greatly beyond the

average; while these three combined account for a further amount of 2,352 deaths, of which 1,688 are infantile. Hydrocephalus shews a slight increase, and measles a very marked one; and these two account for 1,110, of which 1,004 are infantile. From both disease of the heart and from old age, there has been a considerable increase of deaths; both are in excess of the average, and together have carried off 860 persons. We have thus seen the causes of nearly 10,000 of the deaths of the year. The remainder of the numerous diseases which have proved fatal, have, with a few exceptions, each carried off only a small number of persons; and among these, small-pox may merely be noticed in passing, as it has now fallen to occupy a very insignificant place indeed, having only carried off 7 victims, all infants. If the continued immunity in Scotland from this disease is not attributable to the Compulsory Vaccination Act, there is a marvellous coincidence in the cessation of the disease and the application of the measure. Let us go back a very few years, and regard the figures. Even so lately as 1863, there died of this disease in Glasgow 349 persons, and in 1864, 300; but going no further back than the period extending from the years 1852 to 1854, we find that even then it was a still more formidable malady, having carried off in these three years respectively the numbers of 584, 296, and 467. As illustrative of the altered views with which this disease has latterly come to be regarded, there was a recent article in the *Lancet*, calling attention to the remarkable mortality caused by small-pox in Paris, which, in the hospitals, had during the year 1869 carried off as many as 270 victims. The figures given in the preceding paragraph point to a very different state of matters with ourselves, when our population did not amount to one-fourth of the present population of Paris, and yet at that time the subject caused among us no great extent of alarm or even of observation.

I have had occasion, in the course of these remarks, to allude to the Registration Act, which came into operation in Scotland for the first time in 1855. The system had been introduced into England in July, 1837, and became rapidly appreciated and recognized. Our local authorities, impressed with the importance of the subject, desired to obtain for ourselves some such statistics as were thus ascertained, and after waiting until 1851, in disappointed expectation of the extension of the system to Scotland, they instructed the intelligent superintendent of the Corporation burying-grounds to furnish returns, from all the burying-places within the boundaries, of the number of burials, together with the causes of death. These

were tabulated and printed monthly, following as nearly as was practicable the arrangement adopted by the English Registrar-General; and during the period which they include—viz., from April, 1851, to December, 1854, when they ceased to be required—they furnish certain interesting information as to the mortality of Glasgow, not otherwise available. The success of the scheme, so far, induced the authorities to extend the amount of information, by including in the returns, from January, 1852, the number of baptisms as recorded in the parish registers, and the proclamations of marriage, as also recorded in the registers, in the hope of thus obtaining a complete record of the three great statistical data,—the births, deaths, and marriages of the community. The result of this latter portion of the scheme furnishes a notable instance of the necessity for compulsory enactments in all matters capable of concealment, yet requisite to be known. The births so registered were found to be recorded in the three years, 1852 to 1854, as 7,920, 7,957, and 8,735, or not very greatly more than one-half of what we now know must have been the reality. On such terms the city would have become rapidly depopulated, when we look to the heavy amount of mortality prevailing. It has since become evident how vast a disproportion there then existed between the number of births and the record of baptisms. On the other hand, the record of proclamations of marriages might have been found to afford nearly as much of a puzzle; for, in the three years named, they amounted respectively to 4,160, 4,348, and 4,662, or an average of 4,390 a year,—numbers which, with regard to actual marriages, are scarcely approached even until this day; for the average of the last nine years, including 1869, is only yet 3,909, among a population increased by about 100,000 souls. At the first glance, the obviously available inference would be, that a very remarkable number of persons must, after being proclaimed, have thought better over the matter, and allowed it to drop; but there is a simpler and more satisfactory solution in the fact, that proclamations of parties belonging to *different* parishes must each be published in *both* parishes; and we therefore prefer to adopt the conclusion that a large number of marriages proclaimed in Glasgow must have been solemnized elsewhere.

The difficulties, however, which are thus presented by these births and marriages, do not exist in connection with burials. The registrars of the present time take no account of the still-born,—they neither regard them as living or dead, as births or as deaths; but although these little ones thus escape registration, yet they

must find a grave; and if, therefore, we deduct the number of their little resting-places from the total number, we may even still regard the registered number of burials—at least, it was so at the period in question—as a reasonably reliable measure of the amount of mortality; the few who are carried away to be buried with their kindred beyond our limits may be considered as balanced by an equal number who are similarly brought for interment within our own boundaries. I verified this fact in 1863 and 1864, when I found that the number of burials exceeded those of the registered deaths, by numbers not greatly varying from those which still-born burials might be expected to account for. I need scarcely add, however, that now, year after year, the extension of our immediate suburbs in every direction renders this measure of reference less and less reliable, until the time arrives—and it seems now to be not distant—when we shall "bury our dead out of our sight" in localities considerably removed from the busy haunts and homes of living men.

But this dark story of mortality is not without some relieving features; and much as we were startled and surprised last year, week after week, by the Registrar-General's reports upon our rate of mortality, I daresay that many readers will be equally surprised when told that, unsatisfactory as our sanitary condition has been, it is actually somewhat superior to what it was twenty years ago. I do not allude to the terrible year 1847—that which followed the potato famine—when shoals of destitute beings flocked into Glasgow, both from Ireland and the Scotch Highlands, to seek an asylum and a grave, and the deaths of the city exceeded 18,000; but I allude to the series of years commencing with 1848, and terminating with 1854. During these seven years, the aggregate of deaths amounted to 93,453. No doubt that period of time included no less than two invasions of cholera; but, striking off in round numbers 7,700 victims as having fallen before that destroyer, there remain 85,753, or after deducting the liberal allowance of 6,753 for still-born, which at that time were reckoned in the mortality returns, there remain 79,000 other deaths of ordinary occurrence, forming an average of 11,286 for each of the seven years in question. Let us now compare these seven years with the seven years last past. During these last seven years the mortality has averaged 13,683 a year, and it thus exhibits an increase of 2,397 deaths over the corresponding average in each year of the preceding period in question. But how stands the population at the respective periods compared?

If we adopt the calculation of the Registrar-General, that in the middle of 1869 it was 458,937, and assume that at 30th June, 1866, the middle of the seven years now under comparison, it was 438,000, and again, that at 30th June, 1851, it only amounted to 334,000, we arrive at the conclusion—not a flattering one undoubtedly, but yet it is more satisfactory than might have been anticipated—that while the general mortality of the city was, excluding cholera, 33·80 per 1,000 in the seven years, 1848 to 1854, it had abated to 31·24 in the seven years ranging from 1863 to 1869. In short, it would thus appear that the average mortality of the seven years, 1848 to 1854, actually closely approached that of the severely exceptional year 1869.

The local published register, ranging from April, 1851, to December, 1854, alluded to in a preceding paragraph, had naturally a very limited circulation, and copies are now exceedingly rarely to be found. I have consequently regarded it as desirable to take the present means of preserving, to a certain extent, some portions of the information it affords of the details of the mortality of the period which it includes. Accordingly, I have compiled a condensed table of the monthly sequence of deaths from sixteen of the more fatal diseases from which our population suffered, and have added the corresponding details, which are of sad interest, regarding the latest serious visitation of cholera. The table, therefore, will be found to afford very interesting means of comparing the progress or recess of the various diseases enumerated during the years in question, with their position during later periods.

SELECTIONS FROM THE MORTALITY BILL OF GLASGOW FOR THE YEARS 1851 TO 1854, COMPILED FROM THE MONTHLY TABLES PREPARED AND PUBLISHED FOR THE CORPORATION AT THAT PERIOD.

Years.	Small-pox.	Measles.	Scarlatina.	Hooping-cough.	Croup.	Diarrhœa.	Influenza.	Typhus.
1851, . .	672	648	149	783	171	849	112	391
1852, . .	584	241	481	639	204	750	52	504
1853, . .	296	1040	908	839	210	869	53	703
1854, . .	467	329	564	1,026	193	871	51	460

Years.	Dropsy.	Phthisis.	Hydrocephalus.	Apoplexy.	Disease of Brain.	Disease of Heart.	Bronchitis.	Asthma.	Cholera.
1851, .	224	1,904	373	128	162	207	324	162	...
1852, .	312	1,980	393	131	142	153	433	202	...
1853, .	379	2,490	454	146	167	305	513	258	151
1854, .	292	2,350	388	124	129	226	394	175	3,741

It has long been observed, although recently more attention than formerly has been attracted to the subject, that with regard to births and deaths, and also marriages, the ratio increases remarkably wherever large numbers of people are massed together. I do not, of course, allude to actual increase, for that is self-evident, but to a greater *rate* of increase in large than in small communities. The Registrar-General gives expression to his views on the matter in very striking, and possibly, one may be pardoned for suggesting, in somewhat positive language, but indicating at all events, very forcibly, how artificial is the condition of human existence in towns and cities, as compared with the rural and more natural state of man. He says:—"It would appear that nature does nothing without a compensation, although this fact seems hitherto to have been entirely overlooked." [?] "Thus, if the principal towns have the greatest proportion of deaths, they have also the highest proportion of births and marriages, while each of the other groups have their births and marriages in exact proportion to their deaths. In fact, the now ascertained facts, when looked at from a philosophical point of view, would seem to lead to the conclusion, that it was a law of nature that the rapidity of the circulation of life in each country was dependent on the density of the population; and that if the lamp of life burned out most quickly where the population was most dense, ample provision was made for keeping up the supply of life, seeing that, in proportion to the density of the population, the ratio of both marriages and births was correspondingly increased."

Without absolutely adopting a conclusion so peculiarly *definite* as that of the Registrar-General, with regard to the exactitude of the proportions of the various events of births, deaths, and marriages, we may illustrate the fact, of the highest proportion of each being exhibited in the largest towns, in a general way, by

a reference to the events in question as developed in our own city during 1869.

In the preceding, as well as the following calculations, there has been adopted the estimate of our population in the middle of 1869, made by the Registrar-General, as 458,937, because it unfortunately happens that I require to be in the printer's hands some time before my own estimate, founded upon the ascertained number of inhabited dwelling-houses, can possibly be available. However, the difference in estimate cannot be a very important one; and taking the Registrar's figures as to population to be reasonably accurate, it thence follows that our birth-rate has been 40·29, and our death-rate 34·07,—both remarkably high figures when we reflect that the average rate of the whole United Kingdom was, in the same year, 35·34 for the former, and 22·64 for the latter; but we must not lose sight of the fact that both of these last rates are applicable to the *whole* population of the kingdom, in town and country combined, while we in Glasgow are in a very considerably exceptional position, as to both the one and the other, when we look to the density of our population, and apply the remarks contained in the preceding paragraph.

On looking to the year 1867, which is the latest of which the details have yet been tabulated, and dividing Scotland into four great groups—viz., of principal towns, with above 25,000 inhabitants each; of large towns, having 10,000 to 25,000; of small towns, of 3,000 to 10,000 inhabitants; and of rural districts, having among them 1,423,621; while the town groups (already alluded to) have among them 1,747,138,—we shall find the birth-rate to stand in the following proportion, proceeding in the order just now indicated:—41·18 in the principal towns, 39·16 in the large towns, 36·33 in the small towns, and only 31·75 in the rural districts. Similarly applying the death-rate, we shall find it to descend the same scale in the following proportions:—27·99, 24·91, 21·89, and in the rural districts only 17 in the 1,000; and so wondrously steady are these proportions, that, taking the considerable period of ten years, from 1856 to 1865, which offers a more satisfactory field of observation than any single year can possibly do, the proportions are found to be 28·25, 24·57, 21·24, and 16·95.

Of the births in Glasgow during 1869, 9,418 were boys, and 9,072 girls; while of the deaths, 7,840 were males, and 7,800 females. Thus the proportion in births of boys to girls was 103·8 to 100, which is a lower proportion than is generally found to prevail in Scotland, and likewise in Europe generally, where the

rate is almost exactly 104; and this last is a trifle lower than that of England, which is 104·4 to 100.

We may now allude to the remarkably high proportion of marriages registered in Glasgow, which in the year 1869 amounted to 4,221. This number represents a trifle beyond 9 in the 1,000 of population, the exact figures being 9·19; and thus verifies to a considerable extent the estimated proportion for the principal towns already referred to, which is taken as 9·36; while that of the second class, or large towns, is 7·92; of the small towns, 6·83; while in the rural districts it falls to 5·61. The marriages in Glasgow during 1869 exhibit an increase of fully 10½ per cent., as compared with 1868, when they amounted to 3,814; but it is only fair to remark that this last represents the lowest number since 1863.

It may be interesting, before leaving the last subject in hand, to bear in mind a simple circumstance, as illustrative of the minute details which frequently go to affect either a fact or an estimate. The closing day of the year, or in popular language, "Hogmanay," forms the favourite wedding time of the working classes, although Friday is their favourite day, or rather evening, for this ceremony, at almost all other periods of the year. Now, it is obvious that the marriages of the evening of the 31st December cannot possibly be registered until January of the succeeding year; and as it is the date of registration, not of the occurrence, that is tabulated, it follows that each year derives some credit, not exactly its own, in the shape of all the marriages celebrated upon that auspicious day; and upon this occasion, those registered in the month of January amounted to the large number of 537, against 511 in the January of the preceding year. It is only just, however, to add that 1869 sustains a greater loss at its close than compensates its gain at the beginning; for as the year opened upon a Friday, so not being leap-year, it also closed upon a Friday; and the year 1870 thus adds to its statistics the whole of the marriages arising from the double event of the close of the year and the favourite Friday happening together. Thus, the registers of January, 1870, present the unprecedented number of 627 marriages in Glasgow; and a very large proportion of these are recorded, as might be expected, in the very first week of the month. The marriage records of the year exhibit the invariable and certainly peculiar features noticeable in the history of our community year after year; the falling off in February after the excitement of the preceding month, whether belonging to itself or to the closing day of the bygone year; the

comparative dulness of March and April; the great diminution in May, arising from a deep-rooted prejudice; the natural rebound in June; the remarkable outburst at the Fair-holidays in July; and again, the large accession of numbers in November, when the engagements of many domestic servants terminate, and their earnings become available for a start in life. As a matter of course, a similar result would become apparent in May, but for the action of the prejudice already alluded to, against that usually cheerful month.

The number of marriages in a community has been regarded by some statists as affording a reliable indication of the condition or progress of commercial affairs. I am inclined to think that you will coincide with me in entertaining a doubt as to whether the increased number of marriages in 1869 tends to strengthen that view as one which furnishes a rule that is *invariably* to be depended upon.

Having already mentioned the total amount of births during the year, and estimated their ratio to the population, I beg to exhibit the following details of their sequence, and other requisite particulars, for each month of the year:—

January, . .	1,530,	of which	763	were males, and	767	females.
February, . .	1,401	,,	684	,,	717	,,
March, . . .	1,715	,,	865	,,	850	,,
April, . . .	1,704	,,	848	,,	856	,,
May, . . .	1,547	,,	802	,,	745	,,
June, . . .	1,615	,,	819	,,	796	,,
July, . . .	1,583	,,	823	,,	760	,,
August, . .	1,462	,,	730	,,	732	,,
September, . .	1,408	,,	722	,,	686	,,
October, . .	1,483	,,	769	,,	714	,,
November, . .	1,504	,,	831	,,	673	,,
December, . .	1,538	,,	762	,,	776	,,
	18,490		9,418		9,072	

As usual, the male births preponderate over those of females; and likewise, as usual, the second quarter of the year exhibits a preponderance of births over any other trimestrial period, the sequence being,—

First three months, ...	4,646
Second ,, ...	4,866
Third ,, ...	4,453
Fourth ,, ...	4,525

But, as if to vindicate the year's claim to be regarded as in many matters an exceptional one, the usual preponderance of births in April or May over any other month, which, however, in 1868 had been transferred to June, is, in 1869, handed back to March, for it alone records 1,715 births, while the monthly average of the year is 1,541. No doubt, April almost maintains its usual place; still, it is 9 births behind upon this occasion. It is not among our own population only that the usual preponderance of the second quarter of the year is experienced, but it is a general feature of our country; while in many of the Continental nations, February and March are generally observed to be the most prolific months.

A summary of the mortality of 1869 for each month, distinguishing ages and sexes, is shewn in the following table:—

	Males.	Females.	Total.	Under Five Years.	Five to Twenty.	Twenty to Sixty.	Sixty and upwards.
January, . .	688	708	1,396	687	166	365	178
February, . .	675	648	1,323	696	107	369	151
March, . .	893	875	1,768	890	198	476	204
April, . .	745	730	1,475	708	171	420	176
May, . .	701	686	1,387	682	142	417	146
June, . .	657	652	1,309	602	170	386	151
July, . .	639	582	1,221	605	154	345	117
August, . .	495	518	1,013	468	116	321	108
September, .	443	472	915	400	122	297	96
October, . .	502	478	980	472	125	261	122
November, .	645	668	1,313	604	129	403	177
December, .	757	783	1,540	725	128	450	237
	7,840	7,800	15,640	7,539	1,728	4,510	1,863

Here it will be observed that there is a slight preponderance of male over female mortality, which is almost invariably the case in Glasgow. As a general rule, however, taking the whole of Scotland into view, the preponderance is upon the other side; for in the whole period of thirteen years, from 1855 to 1867, both inclusive, it only happened once—viz, in 1856—that the male deaths were in a majority; and this was found to be the case in that year, both in the rural and in the town districts. As a general rule, however, the female deaths exceed those of the males, not only in the rural districts of Scotland, but in the kingdom as a whole; while in the town districts the proportions fluctuate; for in the thirteen years in question, the female deaths were nine times in the ascendant, and

in four, the male deaths occupied that position; and yet, during that long period, which included 408,355 deaths in the town districts, the preponderance of female deaths in so large a number only amounted to 1,877. On the other hand, in the rural districts (excluding the islands, and these present similar results), which exhibit a total during the period in question of 420,435, or not greatly more than that of the town districts, the female preponderance was 2,743.

These are merely results; but the following comparative details of the mortality of the sexes in Scotland, during the decennary extending from 1856 to 1865, will be found interesting. It follows the classification already alluded to:—

Divisions.	Population in 1861.		Male Deaths in Ten years.	Female Deaths in Ten years.
	Males.	Females.		
Principal Towns, .	407,839	477,116	124,631	125,363
Large Towns, .	119,602	134,428	30,981	31,438
Small Towns, .	239,074	265,223	53,307	53,826
Rural Districts, .	683,333	735,679	119,186	121,450
	1,449,848	1,612,446	328,105	332,077

It will thus be observed that in every one of these divisions, as well as in each aggregate, the female element preponderates, not only in the numbers alive, but in the numbers who die. But looking to the prodigious disparity in the proportions of the two sexes, with respect to life and with respect to death—reflecting that while the living females are here shewn to exceed the living males by fully 11 per cent. (the precise fractions are not here requisite), and the mortality of the females only exceeds that of the males by 1¼ per cent.—it follows as a necessary consequence, that male life must be terribly more subject to fatalities than female life is.

The following figures indicate the respective rates of mortality during the same ten years, arranged according to the divisions already given. Of course, it must be borne in mind that these rates of the respective sexes are not applicable to the whole population, but that the calculations as to male deaths apply to the male population only, and the female deaths to the female population only. The combined rate of the mortality of the two sexes is, however, separately exhibited.

Divisions.	Per Centage of Male Deaths.	Per Centage of Female Deaths.	Total Per Centage.
Principal Towns, ...	3·056	2·627	2·825
Large Towns, ...	2·903	2·338	2·457
Small Towns, ...	2·233	2·029	2·124
Total Town Districts, ...	2·725	2·402	2·553
Rural Districts, ...	1·744	1·651	1·695
All Scotland, ...	2·263	2·059	2·156

A very cursory glance at this table indicates most forcibly how highly artificial—in fact, how entirely abnormal—is the human life which is spent among the masses of individuals who constitute towns.

As a matter of course, by removing the decimal point a single place to the right, we shall ascertain the mortality per 1,000, that being the ratio now most usually quoted with respect to vital statistics; and we then find that, while in the great towns of Scotland the mortality during an average of these ten recorded years was found to be 28·25 in the 1,000, it fell in the next class of towns to 24·57, in the small towns to 21·24, and in the rural districts, which embrace nearly one-half of the entire population, it was so low as 16·95, or a fraction under 17 in the 1,000. I may add that the Registrar-General of England is of opinion, that a figure something like this last given is the natural and proper ratio for Great Britain, and that any advance upon it is attributable to causes which men have it within their own power to obviate. I fear that it will require a good deal of education to be bestowed upon our own community before a consummation so desirable is accomplished.

The number and relative proportions of the marriages celebrated during 1869, as well as the peculiarities which mark their periodical fluctuations, have been already noticed upon preceding pages, and I now beg to exhibit their monthly sequence during the year, thus:—

January, ...	537	September, ...	271
February, ...	223	October, ...	288
March, ...	250	November, ...	442
April, ...	273	December, ...	331
May, ...	215		
June, ...	551	Total, . . .	4,221
July, ...	600		
August, ...	240	Average per Month, . .	351¾

A glance at these figures will sufficiently verify the remarks already offered upon the subject of the regularity of the recurrence of the periodical fluctuations of marriage.

I beg therefore to dismiss the subject with a table exhibiting the marriages of every month in Glasgow during the last nine years. An examination of the details will further verify the undeviating existence of the peculiarities already discussed, while it furnishes a very extended field for observation.

MARRIAGES DURING EACH MONTH OF THE NINE YEARS, 1861 TO 1869.

	1869.	1868.	1867.	1866.	1865.	1864.	1863.	1862.	1861.
January, . .	537	511	524	566	548	524	482	410	390
February, . .	223	223	227	267	250	239	240	194	199
March, . . .	250	231	237	223	229	222	252	232	209
April, . . .	273	228	259	308	198	284	246	202	239
May, . . .	215	144	169	206	221	204	171	145	164
June, . . .	551	473	493	557	528	454	460	451	406
July, . . .	600	530	536	532	559	510	512	481	466
August, . .	240	253	237	258	238	254	200	220	194
September, . .	271	253	271	303	256	272	231	254	262
October, . .	288	257	257	315	322	287	312	258	264
November, . .	442	396	385	421	439	379	407	305	354
December, . .	331	315	327	360	380	350	312	305	333
	4,221	3,814	3,922	4,316	4,168	3,979	3,825	3,457	3,480

THE INFANTILE MORTALITY OF 1869.

As usual, I devote a brief but separate paragraph to the infantile mortality of the past year. That of 1869 will be observed, by a reference to the table given upon page 276, to have amounted to 48·20 per cent. of the whole; yet, unsatisfactory as this rate is, it really falls by nearly 2 per cent. under that of the preceding year. The following table exhibits in detail the infant deaths as they occurred in each registration district of the city, together with a comparative statement of the proportion of these deaths to the whole deaths in each district. It will be found to range from 56·81 in the Clyde district, down to 38·48 in the Central district, and few readers will be prepared for another of those peculiarities so continually presenting themselves,—that while the aggregate amount of deaths in the Central and High Church districts is in each very much greater than in any other district of the city, the ratio of infantile mortality is likewise in each the lowest of

them all. The number of infantile deaths will be noticed to vary by a trifle from that given upon page 276, but some discrepancy is almost inevitable, arising from the different modes of ascertaining the particulars, and it is scarcely to be obviated, without devoting more time and labour to their absolute verification than is requisite for the purposes in view. These slight differences cause this table to exhibit 47½ per cent. as the ratio, which in reality presents a variation of, as nearly as may be, only ¾ per cent. from the result shewn by the other table. This last, however, I regard as the more reliable of the two with respect to aggregate; but the details given in the following table are of considerable interest with respect to this particular subject.

THE INFANTILE MORTALITY OF 1869, ARRANGED IN REGISTRATION DISTRICTS.

Registration Districts.	Under One Year.	One Year and under Two.	Two Years and under Five.	Total Deaths under Five.	Total Deaths at all Ages in each District.	Proportion under Five to the whole Deaths in the District.
						Per Cent.
Central, . .	493	239	238	970	2,520	38·48
High Church, .	412	271	299	982	2,508	39·15
Bridgeton, . .	394	295	276	965	1,800	53·61
Calton, . .	298	197	213	708	1,294	54·71
Clyde, . .	256	152	159	567	998	56·81
Blythswood, .	148	79	69	296	735	40·27
Milton, . .	320	142	179	641	1,217	52·61
Anderston, .	345	218	206	769	1,422	54·08
Tradeston, . .	306	188	98	592	1,440	41·11
Hutchesontown,	388	269	282	939	1,707	55·00
	3,360	2,050	2,019	7,429	15,641	47·48

THE HIGH MORTALITY OF 1869.

In many of the preceding pages this topic has been adverted to in detail; but before finally leaving the Vital Statistics of the city, allow me to revert to it briefly.

The very high and exceptional mortality of the year has naturally attracted a very large amount of interested attention to the subject, and many theories have been suggested and much valuable discussion elicited. No universally-accepted explanation has, however, yet been propounded; and it is obvious that still further observation, discussion, and induction will be required before we arrive at a solution of the momentous question. The

pollution of the river—the filthy condition and improvident habits of a portion of the population—intemperance—the excessive issue of smoke—the depression in trade—the faulty nature of the architecture of the older portions of the city—the overcrowding long noticed, but more recently aggravated, through the removal of many tenements—and the tenacity with which the people ejected cling to certain localities,—all these, and others, as well as the effects of atmospheric influences, have each had their supporters; but I fear that we must regard them as all combined in a greater or less degree, but especially with the last-named element, to produce the effect in question. We must bear in mind, too, that similar causes are always more or less at work among us, and that the rate of our city mortality is not steadily progressive, but wandering, uncertain, and spasmodic. In illustration of this, let me remind you that while the mortality of 1861, 1862, and 1863, advanced somewhat steadily, that of 1864 and 1865 was little else than stationary; again, in both 1866 and 1867, it actually fell considerably under that of any one of the three preceding years; then 1868 rose to be equal to 1865; and, lastly, as we well know, 1869 made a sudden and fatal bound. It is impossible thus early to form any estimate of 1870; but it is gratifying to find that the aggregate mortality of the first three months ranges even 7 per cent. under that of the corresponding three months of 1869, while March, taken by itself, is greatly more favourable.

The majority of opinions, upon the subject of the increased mortality that has been experienced during last year, seems to lay the leading stress upon overcrowding and its consequences; and doubtless much of the evil, but not all, is attributable to this important cause. It is one, nevertheless, extremely difficult to grapple with, for it is singular with what tenacity the humbler class of our fellow-citizens cling to localities. The destruction of their houses, and the natural yearning for fresh air and open prospects, are all overbalanced by this strange infatuation for herding together in communities. I shall offer four illustrations of this fact; and for this purpose I select them from one of the most densely-populated portions of the city, which at the same time is marked by the peculiarity of having been the chief theatre of the operations of the Union Railway Company, and of the City Improvement Trustees; and the following is a statement of the number of families found in these respective blocks towards the end of the spring in each of the last four years.

The first is that bounded by Saltmarket on the west, South St. Mungo Street on the east, Greendyke Street or the Green on the south, and by the Gallowgate on the north. Well, then, the number of families—for I have no means of particularizing the individuals—stood thus:—

1866,	1867,	1868,	1869,
2,015;	1,983;	1,936;	2,020;

and yet you all know how much property to the east of, and parallel with, Saltmarket has been removed during the period.

The next block is that bounded by Candleriggs on the west, High Street on the east, Cannon Street and continuous lane on the north, and Trongate on the south. And how stands it here? The sequence of numbers is—

1,292, 1,295, 1,286, and 1,289.

The third block I shall advert to is the large and dense one bounded by Trongate on the north, East Clyde Street on the south, Stockwell on the west, and Saltmarket on the east; and here, you know, the Union Railway makes a diagonal sweep through the entire block. The numbers were found to be in the same sequence—

3,300, 2,995, 3,025, and 3,001.

The last block I allude to is the considerable and squalid one bounded by High Street on the west, Hunter Street on the east, Old Vennel and Graham Street on the north, and Gallowgate on the south; and here also, you are aware, the Union Railway strikes diagonally through the entire space. The numbers were found to be—

1,677, 1,689, 1,674, and 1,676.

Thus these four blocks which I have divided, although forming one connected area, have been found to contain, in all,—

1866,	1867,	1868,	1869,
8,284;	7,962;	7,920;	7,986;

or a difference of almost exactly 300 families. I should add that these 8,000 families are located upon a gross area—including railways and clear space—of as nearly as possible 90 acres; thus giving (if we adopt the family number as five) a population of 440 individuals to the acre over the whole space.

Now, these are startling facts,—for I hold them to be facts, since I have verified them from the books of the Water Commissioners; and each individual figure given represents one family assessed for water,—in short, each figure represents an inhabited house. It is possible that in the earlier years of the period the number of empty houses may have been considerable, and

that they have since become occupied; but still the fact remains, that in an area whose available uses are very greatly circumscribed, the population has remained until last year almost unaffected by the changes going on around. I fear that this continued amount of population arises from the subdivision of holdings, and that dwelling-houses, which at one time consisted of two or more apartments, now accommodate a greater number of families than before. It is quite aside from the subject to complain of single apartments being each occupied by a family, for such has always been the case, and apparently will continue to be the case, much as it is to be regretted. The chief evil arises when a dwelling-house becomes subdivided into single apartments, each entering through its neighbour, in place of each opening only upon a well-ventilated staircase or corridor. Some readers may not be prepared to learn that, at the census of 1861, more than 28,000 houses in Glasgow were found to consist of but a single apartment, and above 32,000 to consist of two; so that of the whole 82,000 families composing the city, upwards of 60,000 were housed in dwellings of one and two apartments each.

Let us make an attempt to ascertain the sanitary relations of this area. Well, then, without going into details very minutely, and regarding this rather as a general statement, we shall arrive at the following general data as to the year 1869. The population was, as nearly as may be, one-twelfth of the whole city; the mortality from all causes was about one-tenth of the whole; and the mortality from certain diseases, as compared with the total mortality from the same diseases, stands approximately as follows:—Scarlet fever, one-twelfth; hooping-cough, one-twelfth; consumption, one-eleventh; diarrhœa, one-ninth; measles and typhus fever, each from one-seventh to one-eighth; and bronchitis and diseases of the respiratory organs, one-ninth.

On referring to Dr. Gairdner's sanitary map of the city, which he divides, for professional and official purposes, into fifty-four districts, I find that the area which I have here selected includes his four districts, 21 to 24, two districts 30 and 31, about two-thirds each of 29 and 32, and about one-eighth of 20. In 1861, this area of 90 acres contained a population of 41,000, or between one-ninth and one-tenth of the population of the city; so that the entire population, if arranged with a similar density, might have been crowded upon less than 860, in place of the 5,034 acres included within the municipal boundaries. Looking to the uniformity of tenure exhibited in this comparison of four years, we may regard the

population of the area in question to have been still in the proximity of 40,000, as already stated, although it is reduced *now*.

This calculation exhibits only the population found to be actually resident upon a particular spot of ground, but of course it is an exceptional instance. Still, if we exclude Liverpool, Glasgow is, as a whole, the most closely-built city in great Britain. In Glasgow the aggregate population upon an acre is 92½; in Liverpool, 101·3; and in Manchester, 83·6; and yet we all know how large are the spaces of unbuilt ground around us, although within the city boundaries, especially to the north-east; but all is being gradually covered over. Of the nineteen largest towns in Great Britain, with the addition of Dublin for comparison, the average density of the population is 33·6 to the acre. I ought, however, not to omit to mention that this average is considerably reduced by the enormous areas embraced within the boroughs of Leeds and Sheffield, which reduce their densities to 12· and 10·8 per acre respectively. Indeed, so considerable is their influence, that were these two struck out of the list, the remaining eighteen cities and boroughs would exhibit a density of almost precisely 39⅓. The following is a list of these twenty cities and boroughs, arranged according to the measure of density:—

Cities and Boroughs.	Area in Acres.	Estimated Population in the middle of 1870.	Persons per Acre.
Liverpool, . .	5,108	517,567	101·3
Glasgow,* . .	5,063	468,189	92·5
Manchester, . .	4,486	374,993	83·6
Birmingham, .	7,831	369,604	47·2
Nottingham, . .	1,996	88,888	44·5
London, . .	77,997	3,214,707	41·2
Edinburgh, . .	4,427	178,970	40·4
Hull, . . .	3,562	130,869	36·7
Bristol, . . .	4,688	171,382	36·6
Dublin, . .	9,745	321,540	33·0
Leicester, . .	3,200	97,427	30·4
Newcastle-on-Tyne,	5,336	133,367	25·
Salford, . .	5,172	121,580	23·5
Bradford, . .	6,590	143,197	21·7
Wolverhampton, .	3,387	72,990	21·5
Sunderland, . .	4,821	94,257	19·6
Portsmouth, . .	9,513	122,084	12·8
Leeds, . . .	21,572	259,527	12·
Norwich, . .	7,472	81,087	10·9
Sheffield, . .	22,830	247,378	10·8
Total, .	214,796	7,209,603	33·6

* A detailed statement of the areas of the various parishes which are included within the municipal boundary of Glasgow discovers the fact, that while it varies to no great extent from the Government area given here, it in reality *extends to* 5,034·538 acres.

In connection with this subject, allow me to add that, a few years ago, Dr. Littlejohn, the Health Officer of Edinburgh, being desirous to ascertain, if possible, the relative bearings of over-crowding and mortality, divided that city into twenty districts, one of them being, however, of a "landward" class, and after deducting the area of all unoccupied spaces of ground, endeavoured to ascertain, in each of the remaining nineteen, the proportion of population to each inhabited area—in other words, its density. He then ascertained the amount of mortality in each; and after calculating the death-rate in each of these areas, prepared a table exhibiting these two important data. I have taken the liberty of recasting that table, with the view of placing it more tellingly than in the original form; and in so doing, have adopted the death-rate, not the population, as the guide of sequence, beginning with the highest on the list. The first and second columns accordingly exhibit the districts arranged according to the order of *mortality;* but the last, which I have taken the liberty of adding, exhibits the same districts numbered in the order of the *density* of the population. The variation in the two scales will be found to be somewhat conflicting and remarkable.

Locality.	Number of District in the order of Mortality.	Mortality per 1,000 of Population.	Persons residing on each Acre.	Number of same District in the order of Density.
George Square and Lauriston (including City Poorhouse and two Hospitals),	1	37·46	76·	12
Abbey, ...	2	36·65	48·6	14
Tron, ...	3	34·55	352·6	1
Grassmarket, . . .	4	32·52	237·6	3
West End, ...	5	31·88	44·2	15
Canongate, ...	6	31·23	219·8	5
Nicholson Street, . .	7	29·	286·	2
St. Giles, ...	8	28·8	234·8	4
Pleasance and St. Leonards,	9	26·65	150·	6
Fountainbridge, . .	10	25·2	114·8	9
Morningside, . . .	11	22·54	8·1	19
Calton and Greenside, .	12	22·12	120·7	8
Newington, ...	13	21·79	39·9	16
Upper Water of Leith, .	14	19·46	88·	11
Broughton, ...	15	17·63	48·9	13
Lower Water of Leith, .	16	17·58	31·1	17
Upper Newton, . .	17	17·38	94·8	10
Lower Newton, . .	18	15·47	126·3	7
Grange, ...	19	13·78	15·9	18

It would be difficult to compare two scales having so little

apparent connection with each other as the first and last exhibited upon the preceding table. Indeed, it seems impossible to draw a reasonable deduction of any value from them, or to attempt to reconcile them; and I think that most of my hearers will agree with me in opinion, that the reasonable inference to be drawn both from the Glasgow and from the Edinburgh tables is, that mere overcrowding is not of itself, however deplorable, an entirely reliable measure of the death-rate, but that there must be other disturbing elements at work, and possibly at war, and so, perhaps, neutralizing each other, to be taken into account; the elements, possibly, of the variations of the human constitution,—of the soil, —of the sewage,—of ventilation,—of the supplies of light and water,—and, I am sorry to place prominently, the very greatly enhanced cost of animal food,—all infinitely commingled. We may well, therefore, be pardoned for avoiding to draw authoritative conclusions, and feel that we are still only learning—only groping. Every statistical truth, however—every tabular exhibition of ascertained facts—is adding its contribution to the great receptacles of knowledge, and lends its aid, however humble, towards solving the momentous problem upon which we are all engaged.

The reading of the paper was followed by a discussion, of which the following is a vidimus:—

Dr. Gairdner, with reference to what had been said regarding soft and hard water, strongly advised the citizens not to be disquieted by the remarks which had been made recently, as the water was not the cause of the high rate of mortality in Glasgow. As to what had been stated in France about soft water tending to the decay of physical power, he pointed to the stalwart men of the Highlands, where the water was almost absolutely pure. He thought it was right that we should face the evils which we had to deal with in all our towns, and especially our great industrial cities. A difficulty of a very serious kind which we had to contend with was this, that our country districts are depopulating themselves gradually into towns. Now, if it was only the population that would be useful and necessary in towns, we might congratulate ourselves upon that fact; but from land falling into few hands in the country, the refuse of the population was coming into the great towns, and the question arose, How are we to deal with it? It is

perfectly clear that if we are to go on as we have been doing for many generations in Glasgow—bringing the houses down to the destitution of the occupiers—we cannot fail to get worse and worse, and the only way to preserve ourselves in a moderate state of purity and health is by keeping up the standard of house accommodation. We must enforce cleanliness and ventilation, and secure ourselves against overcrowding; in fact, we must make it clear to that kind of population that they must mend their habits or quit their occupancy.

Dr. R. Bell held that the cause of the great mortality in the city was not due so much to faulty house construction, bad ventilation, or even to pestilential epidemics, as to the alarming amount of culpable neglect of children, if not in many cases actual infanticide. What they wanted here as much as, if not more than, in England, was the instituting of coroners' inquests. Except the perpetrators of such horrible crimes were punished in a crowded city like this, where opportunities existed of getting rid of children, and more especially in times when work was scanty and destitution more prevalent, they could never hope to bring down the death-rate to its legitimate standard.

Dr. Gairdner, referring to the remarks of the last speaker, pointed out that the number of children who died during last year was less than half of the total number of deaths.

Dr. Lyon said that they never would be able to control diseases until they knew something of their origin, and possibly not even then; but he argued that systematic inquiry into the causes of prevalent and regularly-recurring diseases was necessary to a right estimate of the principal sources of the mortality of the city.

Dr. James Morton thought that the high rate of mortality was not altogether due to faulty house construction, seeing that the death-rate was lower now than thirty years ago, when the houses were inferior to those of the present day. Dr. Gairdner had spoken of making demands on the authorities which would astonish them, and he thought that these should be made without loss of time. He held that the authorities were to blame for allowing the streets to be built in such close proximity to each other; spoke of the importance of having all houses thoroughly ventilated; thought that close beds should be prohibited; and advocated the appointment of surveyors for the city.

Dr. Cowan suggested various measures which ought to be adopted for the improvement of the sanitary condition of the city, and especially the abolition of the smoke nuisance. The excessive in-

fantile mortality of the city was its reproach, and every possible means should be adopted for its diminution.

Mr. Westlands remarked that the evil of overcrowding had been allowed in this city to attain a height which was discreditable to our boasted civilization.

Mr. Macintosh was of opinion that the public authorities were much to blame for permitting the construction of narrow mews and lanes behind the streets in the West End. Many of these lanes came to be occupied as workshops and workmen's houses, and presented the most aggravated forms of overcrowding.

Mr. W. W. Watson made a few remarks in reply, which closed the discussion.

V.—*On the Appearance and Chemical Constitution of Ancient Glass found in Tombs in the Island of Cyprus.* By Mr. John M. Thomson.

Read before the Society, March 23, 1870.

The collection of antiquities, from which the specimens of glass examined were taken, was discovered during the excavation of some ancient tombs, of Greek or Phœnician origin, in the island of Cyprus. These excavations were made under the direction of the Vice-consul Mr. Lang, and the specimens were sent to this country through the agency of Mr. Robert Walker of Letham Hill, by whom they were presented to the Hunterian Museum. They are supposed to be not less than 2,000 years old.

Associated with these specimens of glass were found several articles of pottery, which have not as yet been particularly examined. The articles of glass are generally small in size, of thin construction, and evidently made so as to secure extreme lightness, as all beads or mouldings on them are made hollow. They consist of small vials, flasks, and several round basins, some of which Dr. Young has brought for exhibition to the Society this evening.

In making an examination of the glass, several preliminary points had to be attended to. As obtained, they were covered with a partial coating of sand and clay, which, however, could be easily removed by gentle washing. The objects were then found to be either colourless or with a greenish tint; one or two small glass vials

I noticed to be of a deep purple tinge. They have in general also the appearance of being considerably corroded; and in some parts, the surface of the glass is covered with fine scales having a lively iridescence, and which may be easily removed by rubbing.

The glass is compact in appearance, and with few air bubbles of any size throughout it. The flasks seem to have been made by blowing, as they are of nearly uniform thickness throughout; but the bowls appear to have been manufactured differently, as they are considerably thicker at the bottom than round the edges.

The specific gravity of both specimens was taken, with the following results:—

Specific Gravity of the Green Glass = 2·494.
Do. do. White Glass = 2·513.

From which it appears that the two kinds of glass agree very closely in their specific gravities. Upon comparing their specific gravity with that of other glass which does not contain lead, we find them nearly to correspond.

Glass found in Cyprus,	2·5
Old Bohemian Glass (Dumas),	2·4
Mirror Glass,	2·5

The specific gravity of glass in general varies from 2·3 to 3·6, which is the gravity of Faraday's heavy glass used for optical purposes.

The analyses of these two specimens give us the following numbers as expressing their composition. The results are as follows:—

	Specimen of Green Glass.	Specimen of White Glass.
Silica,	67·980	68·187
Alumina,	2·550	2·700
Oxide of Iron,	1·772	·822
Oxide of Manganese,	2·700	·925
Lime,	6·240	7·730
Magnesia,	...	Trace.
Soda,	17·510	18·460

The analyses were effected in the usual manner, by fusing the glass with pure alkaline carbonates, whilst the alkali contained in the glass was determined in a separate portion by means of hydrofluoric acid.

Upon comparing the results with the analyses of ancient glasses already examined, we find them all very similar in composition: thus, for instance, old Roman glass has the following composition:—

	Silica	Alumina.	Iron.	Manganese.	Lime.	Soda.
Roman Base, .	70·58	1·80	·53	0·48	8·00	18·86
Flatted Glass, .	71·95	Trace.	3·45	0·57	7·33	15·30
Lachrymatory, .	71·45	2·15	1·02	0·17	8·14	16·62

The following is the analysis of glass found in Pompeii, and analyzed under the superintendence of M. Dumas:—

Silica.	Alumina.	Iron.	Manganese.	Lime.	Soda.
69·43	3·55	1·15	0·39	7·24	17·31

We see, therefore, that these glasses are essentially all silicates of soda and calcium, with a certain quantity of iron and alumina, which may have been added, or which may have been extracted from the sides of the pot in which the glass was manufactured, by the action of the alkali when in a state of fusion.

Manganese has also been added in all cases, in order to improve the colour and to oxidize the protoxide of iron, so as to remove the colour which would otherwise have been caused by that substance.

The interest attaching to these analyses, as compared with that of the others quoted, turns upon the fact that the ancients used the same materials, and very nearly in the same proportions, as we do now. It may be noticed, however, that none of the analyses shews the presence of potash, and that only certain very hard modern glasses contain this alkali. Another fact brought out by the analyses which deserves attention is, that the manganese occurs in such a quantity as to indicate that it was added intentionally, and does not exist merely as an impurity. Now, the use of manganese at the present time is to remove the dirty colour produced by iron, and it seems to have been employed by the ancients for the same

purpose. Some of the small flasks previously mentioned, and which I have not had an opportunity of examining, are of a deep purple colour. This, upon analysis, I think, will probably be found to be caused by an excess of manganese.

A third point of interest in connection with these specimens relates to the iridescent colours, which might have been produced by a variety of causes.

It might be due to the contents of the vessels, which had dried up, thus forming a thin coating upon the glass; but in these specimens the coating is upon the outside, the inside being uniform and dull. It might also have been produced intentionally in the manufacture of the glass. After all, however, it is more probably caused by the slow decomposition of the glass, through the action of moisture and carbonic acid, or perhaps of some salts, such as sulphates or chlorides, in the soil, in which they seem to have been imbedded for a very long period.

It is well known, from numerous experiments, that glass is decomposed more or less readily by continued boiling with water and acids. In order to ascertain, therefore, if this ancient glass resembled in this respect our modern ones, a quantity of it in powder was digested in water at 100° C., for forty-eight hours. As was to be expected, it was acted upon readily, for from the green glass there was dissolved out 5·25 per cent., and from the white 4·17 per cent. The substances which were extracted by the water were silica and a small quantity of alkali. The residue from this extract was then treated under the same circumstances with dilute hydrochloric acid, when there was extracted from the green glass 8·023 per cent., and in the white glass 6·400 per cent., in addition to the quantity which had already been removed by the water. This extract consisted of the oxides of iron, alumina, lime, and some alkali.

As this test to which the glass had been subjected might be considered a severe one, another experiment was made in which the natural conditions were more closely followed. Another portion of the finely-powdered glass was suspended in water, and a current of carbonic acid passed through it, by which the following results were obtained. From the green glass there was dissolved 3·642 per cent.; and from the white, 2·361 per cent. We may conclude, therefore, that the glass must have lost some part of its weight during its long entombment.

Ancient glass contains less silica and more alkali than the modern, and is therefore less able to resist the action of solvents.

It is probable, also, that the manufacture was not so good, and the material not so well fused together. This is particularly obvious in two of the bowls, which, by the long exposure, are gradually decomposing; the alkali and other salts are being withdrawn, and they are gradually passing from the state of glass into a porous mass of silica. The iridescence, therefore, is probably nothing else than the gradual scaling off of portions of the glass in plates, thin enough to give the play of colour seen in soap bubbles, and in Newton's rings.

In conclusion, I would remark that if we may judge from the peculiar composition of the glass now brought under the notice of the Society, its difference from the various forms of glass in use in our time, and its general similarity to various specimens of ancient glass which have been analyzed, it may be inferred that we have to do here with examples of really antique manufacture. At the same time, considering the ability displayed at the present day in the manufacture of relics, we would require to be guarded in expressing a decided opinion on the age of this glass.

No light is thrown upon it by the mere analysis, unless by comparison with the other analysis of ancient glass. The description, indeed, of the specimens, lies within the field of the archæologist rather than the chemist, who can do little more than indicate the substances which have been employed in its preparation.

	Silica.	Alumina.	Oxide of Iron.	Oxide of Manganese.	Lime.	Potash.	Soda.
Green Glass found in Cyprus, . . .	67·98	2·55	1·77	2·70	6·24	...	17·51
White Glass found in Cyprus, . . .	68·18	2·70	·82	·92	7·73	...	18·46
Old Roman Base, . .	70·58	1·80	·53	·48	8·20	...	18·86
,, Flatted Glass,	71·95	Trace.	3·45	·57	7·33	...	15·30
,, Lachrymatory,	71·45	2·15	1·02	·17	8·14	...	16·62
Glass found in Pompeii, .	69·43	3·55	1·15	·39	7·24	...	17·31
Modern Glass used for domestic purposes, .	71·70	·40	·30	·20	10·30	12·70	2·3
German Hard Glass, .	69·40	9·60	...	...	9·20	11·80	...
Common Window Glass,.	69·00	7·00	...	...	13·00	11·00	...

VI.—*On the Syenitic Rocks of Westfield, near Linlithgow, with Remarks on the suitability of various Rocks for Harbour Works and Street Materials.* By J. BRYCE, M.A., LL.D., F.G.S.

Read before the Society, May 4, 1870.

ABOUT six miles south-west of Linlithgow, and three miles north-west of Bathgate, an elliptic boss of syenitic rock rises up through the ordinary trap of the Bathgate hills. It is about a mile in length, and from a quarter to half a mile wide at the broadest part, and rises in an elongated ridge, considerably higher than the trap round its borders. The appearances presented at the junction clearly shew that the syenite has been erupted through the trap. It is thus of later origin than the adjoining traps, and is intimately related to other syenites in various parts of the country, which seem to be the latest of the igneous outbursts of plutonic rock which have invaded the sedimentary beds.

The elliptic ridge is flat-topped, the syenite shewing here and there upon it; at the sides it breaks down, in some places very steeply, towards two rivulets, bounding it on either side. When it breaks down thus, the structure of the rock is well seen. It is divided by vertical joints, crossed by others nearly horizontal, into rhomboidal masses, which are often of enormous size; and so great facilities for quarrying are presented. When this system of jointing is on a small scale, the rock puts on that pillared or columnar structure so common among basalts and porphyries, and sometimes seen in granites and granitic syenites.

The structure now described shews that this rock has the position and internal arrangement of an erupted and overlying rock, and not that of a dike, the prismatic masses of which are placed horizontally. It is therefore not probable that the rock has any greater superficial extent than is here seen, or that it would be found intersecting any of the coal workings which lie to the east of it. It seems confined to the limits I have mentioned; but within these, it is in quantity almost inexhaustible. The want of horizontality in the cross jointing gives the rock, in the façades that have been opened on both sides, a lean over towards the north; and this is rather an advantage as regards quarrying, from the situation of the

point at which the rock is most accessible for the means of transport.

The rock has been called a granite, though scarcely with propriety, in the strict mineralogical acceptance of that term. It is, indeed, a triple compound, as granite is; but one of the component minerals is different. Common granite is a compound of felspar, mica, and quartz; the variety called syenite, from Syené, in Upper Egypt, where it was largely quarried for obelisks and temple columns, has hornblende instead of mica, and is thus a compound of felspar, hornblende, and quartz. Our Westfield syenite has the two former ingredients; but instead of quartz, the rarer mineral dipyre; so that it is an intimate mixture of felspar, hornblende, and dipyre. The absence of quartz removes it from the class of granitic syenites, and places it in that of the trap syenites. This slight difference of composition, however, in no way interferes with those most valuable qualities which the stone has in common with the true syenites and other granites, while for some purposes it renders it even superior to them. Its mineral composition renders it incapable of receiving a fine polish, and so unfits it for monumental work, or ornamental architecture; for other purposes the absence of quartz is a positive advantage. The three ingredients are in prismatic forms; and owing to the peculiar state of crystalline aggregation of the rock, resulting from the varied interlacings of the prisms, the Westfield syenite has a most remarkable degree of strength and toughness, while it cannot be ground down into that smooth, polished, glassy surface which quartz takes on, rendering many granites slippery and dangerous as street material. For this purpose I consider the Westfield syenite admirably fitted; while the great lengths into which the stone in the quarry is naturally divided would render it very suitable for kerb-stones. The rock is entirely free from cross seams, and veins of iron or spar, such as traverse many rocks of this class; and it contains *no free iron*, so as to oxidize and exfoliate if exposed in a damp situation. I consider, therefore, that it is well adapted for harbour works; while its great toughness, durability, and strength would enable it to resist, better than any rock with which I am acquainted, all those causes of defacement and destruction to which stone is exposed in the frontings, and upper or street surfaces, of quays and landing docks.

The remarks just made on the Westfield syenite indicate what I consider are the mineralogical principles which should guide those whose duty it is to select street materials. These should be such

as shall be economical, shall wear well, without being expected to be absolutely indestructible, and while exempting us alike from mud and dust, shall reduce to a minimum the chances of accident, and of bodily pain, or mental suffering and anxiety to the patient beasts that minister so largely to our luxury or comfort. Every humane man would set even this latter object far above mere economy. To carry it out with the maximum of economy by means of an indestructible stone is impossible. Such a stone must be a fine-grained quartzose rock, like the granite of Furness, used in many of the streets of this city as a road material, which takes on a high polish, and is dangerous in the extreme. Other granites are less quartzose and more destructible; but no rock of this class can equal those of the hornblendic class in that aggregate of qualities which is required to combine a moderate economy with safety to our persons, and humane treatment of the horse. These rocks differ greatly in their durability; but a skilful mineralogist can always distinguish the durable sorts from those which will wear badly. An abundant supply of the former can be had at no great distance from the city on either side. Such rocks might at least be used on the steeper streets of the city, and on the inclines at the bridges, where gravel and sand are now strewn, in practical condemnation of the rock which has been laid down.

The following analysis of this syenite by Dr. Stevenson Macadam has been kindly made known to me by Thomas Field, Esq., owner of the property at Westfield. Dr. Macadam considers the rock to be very durable, and well fitted to withstand weathering, and to support great weights and strains.

Silica,	70·66
Alumina,	14·43
Oxide of Iron,	3·52
Lime,	2·13
Magnesia,	0·82
Potash,	6·21
Soda,	1·96
Loss in Analysis,	0·27
	100·00

VII.—*On China Grass, Rheea, or Ramee Fibre.* By Mr. William Keddie, F.R.S.E., Sec. Phil. Soc.

Read before the Society, May 4, 1870.

The fibre from which the Chinese have been in the habit, from time immemorial, of manufacturing their celebrated "grass cloth," is the product, not of a grass, but a nettle. The plant has long been known to botanists, first as the *Urtica nivea* of Willdenow, and the *Ramium majus* of Rumphius, and subsequently as *Boehmeria nivea* of Gaudichaud, it having been transferred from the true nettles to a separate genus, including stingless nettles; and derives its specific name, meaning "snowy," from the white under-surface of its leaves. Specimens grown in Sumatra were brought under the notice of Dr. Roxburgh at the beginning of the century, when that eminent botanist was investigating into the qualities of the vegetable fibres of India, and, not being aware of its specific identity with Willdenow's plant, he named it *Urtica tenacissima,* because it was the strongest fibre which he had met with in the progress of his researches. The plant has a wide geographical range, being cultivated in China, Borneo, Java, Sumatra, Singapore, Siam, in various parts of India, and notably in Assam, Rungpore, and Dinagepore, where the moist and warm climate is peculiarly favourable for its production. Although the plant had been familiar to botanists for about half a century, and quantities of the fibre had been imported into this country, especially betwixt the years 1810 and 1816, it was not till a comparatively recent period, when the late Sir William J. Hooker was engaged in obtaining materials for the Museum of Economic Botany at Kew, that he discovered the fibre in question—viz., the Caloee of Sumatra, the Ramee of the Malayan Peninsula, the Rheea of Assam—to be identical with the Chu Ma of the Chinese, with which they fabricate their grass cloth.

The nettles both of tropical and temperate climates are characterized by the tenacity of their fibres. The fibre of the common European species, *Urtica dioica,* has been found suitable for the manufacture of paper and cloth. Several Indian species yield fibres which are utilized by the natives for the manufacture of cordage,

nets, and textile fabrics. *Boehmeria puya* (*Urtica frutescens* of Roxburgh), indigenous to the lower slopes and base of the Himalayas, from the Bhurrampootra to the Ganges, is described as resembling the Chinese grass-plant, and as yielding a fibre but little inferior. In Gharwal and Kumaon, the fibre of this nettle is known as Poee, which, further east, changes into Puya or Pooah. *Urtica crenulata*, common in Eastern Bengal, yields a white and strong fibre, which, however, is said not to be very lasting. The fibre is known as Chor Putta. This species represents in a remarkable degree another characteristic of the nettle tribe—the causticity of their juice. The effect of handling this plant in the Calcutta Botanic Garden is thus described by Leschenault de la Tour:—"One of the leaves slightly touched the first three fingers of my left hand; at the time I only perceived a slight pricking, to which I paid no attention. This was at seven in the morning. The pain continued to increase: in an hour it had become intolerable: it seemed as if some one was rubbing my fingers with a hot iron. The pain rapidly spread along the arm as far as the armpit. I was then seized with frequent sneezing, and with a copious running at the nose. About noon I experienced a painful contraction of the back of the jaws, which made me fear an attack of tetanus. I then went to bed, hoping that repose would alleviate my suffering; on the contrary, it continued nearly the whole of the following night. The next morning the pain began to leave me, and I fell asleep. I continued to suffer for two days, and the pain returned in full force when I put my hand into water. I did not finally lose it for nine days." A workman in the same garden, who was similarly affected by being stung by this nettle, described the sensation, when water was applied to the suffering part, to be as if boiling oil were poured over him. A fine silk-like, soft, and lasting fibre is yielded by *Urtica heterophylla*, a fierce stinger, and described as "a ferocious-looking plant," extensively distributed in mountainous districts of India. The fibre is known in Assam as Horoo Surat, and is extensively used in the manufacture of cloth. Various other urticaceous plants abound at the base of the Himalayas, and from these the hill men extract fibres in small quantity, but no account is given of their value. Nettles in our part of the world are herbaceous plants of comparatively humble dimensions; but in the hot and humid climate of some districts of India, they acquire the bulk of considerable trees. A section of *Urtica gigas*, one of these nettle trees, in the Museum of the Botanic Garden of Edinburgh, measures 20 inches in diameter.

The late Dr. Royle, in his work *On the Fibrous Plants of India*, gives prominence to the China grass or Rheea fibre. He furnishes, from an authentic source, an account of the cultivation of the plant and the preparation of the fibre in China, from which we learn that the culture of the plant is conducted with great care; that it may be propagated by seeds, but more expeditiously by parting the roots, as it throws up numerous shoots; when these are cut down, fresh ones spring up, and thus three several crops are obtained in the season. Great attention is bestowed on the scraping, peeling, steeping, and bleaching of the fibre. The first crop yields strong and coarse fibres; from the second and third crops, delicate fibres are obtained for the finer fabrics.

The most recent information regarding the cultivation and extraction of the Rheea fibre in India is embodied in the *Journal of the Agricultural and Horticultural Society of India*, by George King, M.B., late Officiating Superintendent, Botanical Gardens, Seharunpore, and now Assistant-Inspector of Forests, N.-W. Provinces. The communication bears date, Seharunpore, 10th September, 1869, and its substance will be embodied in what follows.

The nettle yielding the fibre is herbaceous, with large, spreading, much-divided roots, from which rise from seven to ten straight, slender, slightly-branching stems, from the bark of which the fibre is extracted. Naturally twice, but under cultivation, it is said, three, four, and even five times a year, according to climate and soil, a fresh set of stems shoots up from the root. An intelligent practical gardener and good botanist, who has, within the last few years, been employed in the cultivation of *Boehmeria nivea* in one of the Government gardens in India, has stated to me, as the result of his experience, that two crops, and perhaps a third, may be obtained in the most favourable circumstances, but that a larger number is not to be expected. This testimony corresponds to the next statement of Mr. King, who says that in the Government gardens at Deyrah Dhoon, where the object aimed at has been the propagation of the plant, and not the extraction of its fibre, the stems have hitherto been cut down only twice a year. He is nevertheless of opinion that, if well manured and watered, three crops, as in China, might be obtained; and he adds that, in the moist climate of Assam, four or five crops may be obtained in a year. The plant is very hardy, and thrives in parts of India differing so much in climate and other physical conditions as Assam, Bengal, the North-West Provinces, and the Kangra Valley in the Punjaub. It has also been successfully introduced into the Madras Presidency. In

Deyrah Dhoon, some old plants throw up shoots from 8 to 10 feet high, and 6 feet is a common height. An 8 feet shoot, if carefully manipulated, will yield a fibre 6 feet long. Some degree of shade seems favourable; an adequate supply of moisture is indispensable; and in the plains of Upper India, regular irrigation will be necessary. "But," says the writer, emphatically, "of all the requisites for successful cultivation, I believe the first in importance to be manure, and this is the one least recognized in Indian agriculture. The Chinese manure extensively." The propagation of the plant by cuttings is not always a mere matter of choice, its production by seed seeming to be occasionally interrupted by a cause which will interest the vegetable physiologist. "Thus," says the writer, "the plant being one of those in which the male and female flowers are separate, and situated on different parts of the stem, the production of the seed is uncertain in some localities where the insects are not indigenous, by which fecundation is probably for the most part accomplished.* In districts where *Boehmeria* has been introduced, propagation has been conducted, not by seed, but by cuttings, and by division of the roots of old plants. By cuttings it may be propagated very easily, as, with ordinary care, scarcely one fails to strike."

With regard to the cost of cultivation, the writer adds nothing to the estimates furnished fifteen years ago by Dr. Royle, who ascertained from Major Hannay and Captain Dalton, two gentlemen who, at the request of the East India Company, devoted much attention to the growth of this fibre in Assam, that the expense was ten rupees per maund (£28 a ton). Captain Dillon stated that the lowest price at which it was likely to be procurable by purchase from the cultivator was six annas a seer, or about £42 per ton; adding that, "when it is more extensively cultivated, and the best method of preparation understood, so that women and children may be employed as well as men, it ought not to cost more than four annas a seer, or £28 per ton." Major Hannay mentions that £20 a ton was offered for any quantity of the fibre in Calcutta, a sum which Dr. Royle affirms will not pay for the expense of culture and preparation. Messrs. Marshall & Co., of Leeds, the earliest and the most extensive consumers of China grass, writing to Dr. Royle in 1853, estimated the value of the Indian supplies delivered in

* It is presumed that the writer quoted has actually observed that the well-known provision for the dispersion of pollen in urticaceous plants generally, by the elasticity of their filaments, is in this instance aided by the agency of insects. In our common nettle this is not the case.

England at £48 to £50 per ton. They found the Indian fibre inferior in quality to that imported from China, but considered that it would still be a useful material, of which they could take a regular supply. "It would certainly be an important advantage to us, as consumers of China grass or Rheea fibre, to be able to obtain a supply from Assam. If it could be supplied at lower rates than those mentioned, that would, of course, much encourage the consumption of it in this country. At present there is not much consumed in England; but a good supply from a nearer market than China might enlarge the demand."

Reference has already been made to the careful preparation of the fibre by the Chinese. Their processes for separating the fibre are all manual, and appear to vary in different districts. One method is, to soak the stems in water, cold or tepid, according to the season of the year, then to bend them in the middle so as to loosen the fibrous portion from the woody and cellular tissue of the stalk at that point, and remove the fibre by introducing the finger at the opening thus made, and stripping it off. By a simpler method, after softening the stem by steeping it for a short time in water, it is split longitudinally by a knife, and the fibre is then peeled off each half separately. When thus removed, the fibre is scraped in a moist state with a blunt knife, and then bleached by alternate exposure to the sun by day and the dew at night. Boiling with alkalies is also practised in order to secure whiteness. Various other methods are given in detail from the *Imperial Treatise of Chinese Agriculture*, in Dr. Royle's work. As regards the preparation of the fibre in Assam, we have, in the same book, Major Hannay's Indo-Chinese process, which consisted in cleaning the newly-extracted fibre by tying it up in bundles and soaking it in water for a few hours. A bundle, when softened, was put on a hook fastened in a post; and the operator, by taking one strand of fibre at a time in his hand, and passing it quickly through his fingers, completely separated the outer bark from the fibre, the latter being then cleaned by two or three scrapings with a knife. The appearance of the fibre was much improved by exposure on the grass to a night's heavy dew. The colour was improved after drying, and the risk of mildew on the voyage homeward was found to be prevented.

Mr. King's experiments on the preparation of the fibre are described by him as follows:—" Following the directions furnished to me by several Chinamen, I made some experiments on the manual extraction of the fibre. The only stems at my disposal

were, however, rather old and hard, and on that account unusually difficult to manipulate. I, however, learned enough to convince me that the extraction by hand processes is difficult, slow, and expensive. Steeping in water for an hour or two had no effect whatever in facilitating the separation of the fibre from the stem. I tried steeping in plain water, in water with various proportions of unslaked lime in it, and in solutions of potash of various strengths, and for periods varying from a day to a week. The stronger alkaline solutions were the most effectual; but whether the use of chemicals has any deleterious action on the fibre, I am not prepared to say. Seeing that potash is used in the preparation of Russian flax, I should not anticipate any harm from its moderate use. I also tried beating the fibre out of the stems both in a fresh state and after they had been steeped. Pressure I intended to try, but my experiments were limited by a scanty supply of material."

It has been already mentioned that quantities of the fibre were occasionally imported into this country from India between the years 1810 and 1816. When used as cordage, it was found to be greatly superior to Russian hemp. About the last-named date, the application to this fibre of a machine which had been patented by Mr. James Lee, for separating the fibres of flax, resulted in bringing it to a thread, which was described, in a despatch of the East India Company's directors, as being "preferable to the best material in Europe for Brussels lace." Notwithstanding this testimony to its utility, and although the East India Company made strenuous efforts to introduce the substance for textile purposes into this country, the Chinese grass fell very much out of sight, and little more was heard of it till the first Great International Exhibition in 1851. Finely-prepared specimens of the fibre were there shewn, and three prize medals were awarded to the exhibitors. The finer specimens had a silky lustre, resembling the fibres of asbestos; some were dyed of different colours, and some were woven into cloths. In the Jury Report, the process of Messrs. L. W. Wright & Co., for the preparation of Chinese grass, &c., and for which a patent had been obtained in 1849, was described as consisting "essentially in a very ingenious arrangement for boiling the stems in an alkaline solution, after they have previously been steeped twenty-four hours in water at a temperature of 90°. The fibre is then thoroughly washed with pure water, and finally subjected to the action of a current of high-pressure steam till nearly dry. A very beautiful series of specimens (it was added), illustrating the preparation of this fibre, the various stages of the process, the bleaching of it, and

the uses to which it may be applied, both alone and in conjunction with other fibrous materials, in the production of mixed fabrics, was shewn by Messrs. Wright." Messrs. Marshall & Co., of Leeds, were also amongst the exhibitors.

The specimens on the table were prepared by one or other of the processes the results of which were shewn at the Great Exhibition. It is to be observed that the fineness and silky lustre of the fibres have been produced without materially impairing their tenacity. A somewhat similar appearance was imparted to the fibre of flax, about the time when these experiments upon Chinese grass were in progress, by the application of M. Claussen's patent method for the preparation of that substance. His process consisted in first boiling the cut and crushed stems of flax or hemp in a dilute solution of caustic soda; then plunging the fibrous substance into a bath of dilute sulphuric acid; next transferring it into a solution of carbonate of soda; and lastly, immersing it in a weak solution of sulphuric acid—causing the liberation of carbonic acid; thus splitting up and disintegrating the fibre, so as to completely alter its character, and convert it into a material resembling cotton. The fibres of flax and hemp thus treated, no doubt, gained in appearance, but it was at the loss of their really valuable property—their tenacity. Dr. Royle mentions that experiments were made more than a century ago with a view to the conversion of flax and hemp into cotton. In recent times, the attempt to introduce the practice into Germany and Ireland has not succeeded.

"The desideratum of the Indian grower," says Mr. King, "is a chemical process or a machine which shall enable him to effect the rough separation of the fibre from the stem at a cheap rate. The English manufacturer prefers to buy the fibre in this rough condition, and to undertake all subsequent processes himself, as in doing so lies his greatest profit. It was found that the fibre in the rough state is apt to ferment during its passage to England; and to obviate the liability to this, must therefore be a prominent feature in any successful process of extraction. I think it probable," he adds, "that a machine on the principle of Hill & Bundy's, for breaking and preparing the fibre of raw flax, hemp, sunn, and similar plants, without steeping or dew-wetting, might be devised without difficulty for Boehmeria. The framework of Hill & Bundy's machine can be made of wood, and its principle (that of conical longitudinally-ridged rollers revolving independently of each other) being very simple, I think it suitable for being both worked and made by natives. It is possible, however, that the extraction may be cheaply

effected by some chemical process, involving the use of alkalies, and not requiring machinery. Experiments should be made on this point. I hear that a gentleman in Upper India has invented a cheap and effectual process; but as he has not yet made it public, I do not know in what it consists."

The following is an extract from a notification by the Governor-General of India in Council:—"The Government of India, after communication with various agricultural and horticultural societies in India, and with persons interested in the subject, has arrived at the conclusion that the only real obstacle to the development of an extensive trade in the fibre of rheea or China grass is the want of suitable machinery for separating the fibre and bark from the stem, and the fibre from the bark, the cost of effecting such separation by manual labour being great. The demand for the fibre is now large, and no doubt might be extended with reduced prices, and there is a practically unlimited extent of country in India where the plant could be grown. The requirements of the case appear to be some machinery or process capable of producing, with the aid of animal, water, or steam power, a ton of fibre of a quality which shall average in value not less than £50 per ton in the English market, at a total cost, all processes of manufacture and allowances for wear and tear included, of not more than £15 per ton. The said processes are to be understood to include all the operations performed after the cutting and transport of the plant to the place of manufacture, to the completion of the manufacture of fibre of the quality above described. The machinery must be simple, strong, durable, and cheap, and should be suited for erection at or near the plantations, as the refuse is very useful for manure for continued cultivation. To stimulate the invention or adaptation of such machinery or process, the Government of India hereby offers a prize of £5,000 for the machine and process that best fulfil all the requirements named above. Rewards of moderate amount will be given for really meritorious inventions, even though failing to meet entirely all the conditions named."

Mr. King mentions, as the result of experiments in the cultivation of the plant in the Government gardens at Seharunpore and in Deyrah Dhoon, that the Boehmeria grows freely and is easily propagated in Upper India, and that there is an increasing desire on the part of Europeans to engage in its cultivation. "The one great objection to this fibre," the writer remarks in concluding his paper, "is the difficulty of extracting it. The manual processes already mentioned are so very slow and expensive, and Indian

labour is so very much inferior to Chinese, that until a cheap and simple machine be put within easy reach of the cultivator, or a chemical process be invented, Indian grass fibre can never, I fear, enter into competition with Chinese, and little progress can be made in extending its cultivation in this country."

I am indebted to the kindness of Mr. William R. W. Smith for being able to trace the history of the fibre subsequently to the year 1851, since which period little has been heard of it by the general public. He states that some time before that period, Mr. Empson, then a partner of Messrs. Marshall & Co., flax spinners, Leeds, and who had been in Manilla, where he became acquainted with the quality of the rheea fibre, directed his attention to the production of yarns from this substance by the ordinary flax process. Mr. Smith, having at that time business connection with the Leeds house, sold some parcels of this yarn to different manufacturers in Glasgow, but the result was not satisfactory. Some colours could be well brought out in dyeing, but others were dull, and there was no apparent commercial advantage in the use of the material over ordinary flax yarns, inasmuch as, while the lustre was very little more, the price was greatly higher; and when woven into cloth, a comparison of the two fibres was rather to the disadvantage of the China grass. Mr. Smith having, since the announcement of this paper to the Society, made inquiry of Mr. Empson as to the subsequent progress of the manufacture, I am favoured with his permission to quote the following statement from that gentleman's reply, of date, April 12, 1870:—"We have long since ceased to spin China grass material, finding that the yarn produced from it was not liked by the manufacturers of linen goods. But there have been considerable experiments with the material, more especially at Wakefield, with the view of making it available for mixing with wool or worsted; and I understand that there is now a considerable vent for the material, in a prepared state, with the Bradford manufacturers; but I have no sample of the prepared material, or any particulars as to the mode of preparation." Along with this letter, Mr. Empson sent to Mr. Smith a sample of the raw material as imported (now produced), as to which he mentions, in a note of the 18th April, "We had to deal with it by chemical process before we could get it into condition fit for flax machinery. This process," it is added, "reduces the bulk of the stuff immensely, and so increases the cost to the spinner."

Mr. Smith, after referring to the vigorous but unsuccessful efforts of Messrs. Marshall & Co. to introduce this material,

and to the necessity under which they ultimately lay of selling off their yarns at a loss, makes this remark:—"From what I saw then, I came to the conclusion that, unless this fibre could be sent into the market at a lower price than flax, there was no hope of its becoming of any commercial value, and it would seem as if this opinion had been justified by subsequent events. Some years ago, the worsted spinners of Bradford made attempts to produce the yarn by their machinery; and again there was considerable stir in regard to this material, as if something were at length to come out of it; but no sooner was it woven, than the limp cold-feeling cloth was everywhere condemned. Wool was excessively high in price at that time, and the fibre was to a certain extent successfully mixed with it; and there is, I believe, a small trade still doing in this mixed material: but as with Messrs. Marshall & Co., so it was with the Bradford spinners; many of them lost money in attempting to introduce the fibre. The latest attempt of this nature known to me was made by Mr. Lister, who recently addressed the Society on the patent laws. He expected to get the fibre into a profitable state by subjecting it to his silk-combing machine; but so far as his experiments went, he was greatly disappointed, owing to the brittle nature of the fibre and its working into little lumps. He sent to me (and you now have) a piece of the cloth, the warp being cotton, and in this you will see the defect. But here again the price was too high to admit of profit, and there was no apparent commercial advantage in the cloth produced."

Mr. Smith further observes:—"From the samples sent, you will see that the fibre is most beautifully white and silky, and it is little wonder that spinners have been tempted to experiment upon its utilization, but it seems to be one of those materials which get worse the more you work with them; whereas in other textile materials, as cotton, silk, wool, and flax, the usual manipulation produces good effects, and the material seems to improve in the working. It is possible, however, that some successful method may yet be found for treating it; but you will see, from what I have said, that for twenty years past it has beaten us."

Mr. Alexander Harvey, who made experiments upon the fibre in his dyework a year or two ago, remarks to me that, "both in bleaching and dyeing, the fibre loses much of the fine silky lustre which it at first possesses, although it remains much superior to cotton or even flax when so tested. If it were intended that this new fibre should supersede silk or even flax," Mr. Harvey remarks,

"I do not think that the expectation of those who introduced it would be realized. It is, however, rather beautiful, and might be used freely by manufacturers, if the element of cheapness, as compared with other similar fibres, could be secured."

In 1853, when the consumpt of the China grass or rheea fibre seems to have been greatest, Mr. Archer, in his book *On Economic Botany*, reported the annual imports to be between 300 and 400 tons. It being desirable to obtain an authentic statement of the imports from China and India respectively, so as to furnish the means of estimating the progress, or otherwise, of the manufacture during the last few years, I applied for information on that point to Mr. Michael Connal, who very obligingly made inquiries at the Chamber of Commerce in Glasgow, and at an eminent mercantile firm in London. The information furnished by the London house is as follows:—"We have much pleasure in handing you all the information we can procure with reference to China grass. There are no published statistics, which renders it somewhat difficult to get at the exact figures; but there have been no imports of any consequence since 1863, certainly not 50 tons during the last four years, exclusive of last year, when about 150 tons were imported on Bradford account, where it is used for mixing with lustre wools, and these importations were all made on actual orders sent out from this side. Prices range from £65 to £70. From India no imports have taken place, with the exception of a few sample bales of the rheea sort, and all of inferior quality to what came from China. There would no doubt be a large consumption if it could be laid down to sell here at about £50, and of a quality equal to the China sort."

From the Chamber of Commerce the report is as follows:—"In a table of Chinese products exported in 1867 and 1868, notice is taken of grass cloth, the exports of which are given: 1867, quantity exported, 363 piculs, value, 25,412 taels; 1868, quantity exported, 302 piculs, value, 31,820 taels. The value of the Chinese tael is 6*s.* 2*d.* No notice is taken of ramee or rheea among the varied products exported. The whole exports in 1868, classified under the term 'sundries,' were estimated at about 505,000 taels, and the total exports were 69,114,733 taels."

To the above returns it may be added that the commercial reports from Her Majesty's Consuls in China and Siam, for 1869, printed in the Parliamentary blue book, make no mention of any exportation of China grass or grass cloths.

VIII.—*Note on the Action of House Sewage on Lead Pipes.* By MR. EDWARD C. C. STANFORD, F.C.S.

Read before the Chemical Section, December 6, 1869.

THE author draws attention to the rapid deterioration of lead pipes when connected with water-closets. Dr. Fergus had traced a close connection between the existence of various forms of low febrile disease and emanations of sewer gas arising from holes eaten through these soil pipes. In about ten years, the pipes leading from the closet become riddled with holes, and most of the lead itself is converted into a grayish-white substance. Several specimens were examined, with the following results:—

	1.	2.	3.	4.
Carbonate of Lead, ...	2·70	86·00	91·00	92·90
Carbonate of Lime, ...	80·63	2·50	2·10	2·90
Water, ...	·45	1·20	1·00	·50
Oxide of Lead, ...	...	3·50	1·50	1·45
Silica, ...	1·35	2·80	1·00	1·60
Organic Matter, ...	14·87	4·00	3·40	·65
	100·00	100·00	100·00	100·00

In No. 1 specimen, there was evidence that chloride of lime had been used, which accounts for the carbonate of lime. The action is greatest in the upper portions of the syphon bends, in the air-space, and not in the water-spaces or traps. Water free from air does not act on lead, and the effect is probably due to the action of the air and carbonic acid carried down by the rush of water. It is suggested, also, that where there is decomposition, the ammonia evolved from the excreta may act as a carrier; and by cleaning the lead surface, may increase the rapidity of its deterioration. The action does not arise from sulphuretted hydrogen nor from nitric acid, as neither sulphides nor nitrates were found in the specimens examined.

IX.—*On the Estimation of Iodine and Bromine, with special reference to the analysis of Kelp.* By Mr. Robert R. Tatlock, F.R.S.E.; F.C.S.

Read before the Chemical Section, December 6, 1869.

The methods for the estimation of iodine and bromine, in presence of chlorine, that have been devised from time to time, are exceedingly numerous, but in many cases very unsatisfactory. They generally require either extreme skill and nicety on the part of the operator (a very small error in the manipulation seriously affecting the results), or they are so tedious and inapplicable, in most ordinary circumstances, as to be of little value. These remarks apply specially to methods that have been described for the estimation of iodine in kelp, in which the presence of bromine is either overlooked or ignored, although its existence would render such methods totally inapplicable.

The object of the following note is to describe a method for the determination of iodine and bromine, in presence of each other, which I have followed for many years, and which has been perfectly successful in the analysis of kelp. It is not intended to supersede other methods, but merely to take its place along with them, its simplicity in the hands of indifferently-skilled chemists rendering it suitable for adoption in the manufacturer's laboratory—a quality which will be valued more particularly in Glasgow, the seat of the iodine manufacture; while, in point of accuracy, it leaves nothing to be desired.

The method like that of Frederick Field (*Chemical Gazette* for 1857, No. 357) is based upon the wide difference between the equivalents of iodine, bromine, and chlorine; but the mode of procedure is totally different from that of Field, and is not open to an objection which Fresenius has taken to that gentleman's process of determining these three elements. It depends upon the displacement of iodine by bromine, and of iodine and bromine by chlorine. I shall proceed to give the method in detail before referring to its application in the analysis of kelp.

(1.) The solution containing the iodide, bromide, and chloride, preferably in combination with an alkali metal, is divided into three equal portions; or, at any rate, three equal portions of it are drawn

off. To the one, solution of silver nitrate is added in excess, to precipitate the whole of the I, Br, and Cl. The fluid is then feebly acidified with pure nitric acid, warmed, and agitated till the precipitate settles. This is collected on a small weighed filter, washed with hot water, dried as far as possible at 212° Fahr., removed from the filter, dried perfectly by heating to incipient fusion, and weighed, the weight of the small portion adhering to the filter being added, and the weight of the whole noted as—

$$AgI + AgBr + AgCl.$$

(2.) Another portion of the solution is transferred to a small basin, and a quantity of pure bromine-water added. The mixture is then carefully evaporated on an open water-bath, more bromine-water being added from time to time, till the escaping vapours no longer turn starch-paper blue on a fresh addition—shewing that all the liberated iodine has escaped. To insure excess, a little more aqua-bromine is added, and the solution evaporated to complete dryness. The dry residue is then drenched with water, and the result heated till again dry; this operation is repeated two or three times, to insure the complete expulsion of any hydrobromic acid that may have been present in the bromine-water. The residue, which now consists solely of alkaline bromide and chloride, is dissolved in water, silver nitrate added in excess, the solution acidified, and the precipitate collected and weighed in the usual way. It is noted as—

$$AgBr + AgBr + AgCl.$$

(3.) The last portion of the solution is brought into a small basin, and a quantity of strong chlorine-water added, to effect the liberation of the iodine and bromine. The mixture is then evaporated till all colour is gone, and some more chlorine-water added. If the solution remains colourless, the whole of the iodine and bromine has been expelled, and the alkali metal will exist entirely as chloride. The solution is then brought completely to dryness, after which it is evaporated with a few drops of water two or three times, to expel any hydrochloric or hydrobromic acid. The dry residue is dissolved in water, the solution acidified with pure nitric acid, silver nitrate added in excess as before, and the chloride of silver collected as usual. Its weight is noted as—

$$AgCl + AgCl + AgCl.$$

It is obvious that we have now data from which we can calculate the amounts of iodine, bromine, and chlorine present; for, as the

equivalent of bromine is less than that of iodine, in the proportion of 80 to 127, the second precipitate, in which the iodine is replaced by bromine, must weigh proportionately less than the first; and, as the equivalent of chlorine is less than that of either iodine or bromine, in the ratio of 35·5 to 127 in the one case, and 80 in the other, the last precipitate must weigh still less than the second, and we can thus, from the observed differences, deduce the exact quantities of the three elements present.

Example:—

1.	AgI + AgBr + AgCl	weighed	15·57
2.	AgBr + AgBr + AgCl	„	14·69
3.	AgCl + AgCl + AgCl	„	12·20

Then—

IODINE.

I.		II.		Observed Difference.
15·57	−	14·69	=	0·88

Loss for 1 equiv. I.		Observed Loss.		1 equiv. I.		I present.
47	:	0·88	: :	127	:	2·378

BROMINE.

I.		III.		Observed Difference.
15·57	−	12·20	=	3·37

But, as a portion of this loss is caused by the replacement of iodine by chlorine—namely,

Equiv. of I.		Loss in replacing 1 equiv. I by Cl.		I found.		Loss accounted for by I present.
127	:	91·5	: :	2·378	:	1·713

Observed Loss.		Loss accounted for by I present.		Difference for Br.
3·37	−	1·713	=	1·657

Loss for 1 equiv. Br.		Observed Loss on account of Br.		1 equiv. Br.		Br. found.
44·5	:	1·657	: :	80	:	2·978

Then, as the proportions of iodine and bromine are already known, it will be an easy matter to calculate them to iodide and bromide of silver, and deduct their weight from precipitate 1, calculating the remainder (chloride of silver) to chlorine, thus:—

CHLORINE.

	I.		AgI.		I present.		AgI.
	127	:	235	: :	2·378	:	4·400
And—							
	Br.		AgBr.		Br. present.		AgBr.
	80	:	188	: :	2·978	:	6·998
Then—							
	AgI,						4·400
	AgBr,						6·998
							11·398
Then—							
	15·57	—	11·398	=	4·172		
Then—							
	AgCl.		Cl.		AgCl.		Cl.
	143·5	:	35·5	: :	4·172	:	1·032

We had, therefore, present in the solution—

Iodine,	2·378
Bromine,	2·978
Chlorine,	1·032

The bromine-water may be easily obtained free from chlorine by distilling bromide of potassium in solution with less potassium dichromate than is necessary to expel the whole of the bromine, using, of course, a little hydrochloric acid.

We now come to the application of the above method to the analysis of kelp.

It is quite obvious that this process cannot be directly applied to substances containing I, Br, and Cl, in very different proportions, and consequently it cannot be used for the estimation of these elements in kelp immediately, nor is it applicable to the estimation of the chlorine at all, in the case of kelp. The following method of treatment will be found to equalize as nearly as necessary the proportions of the three.

2,000 grs. of the kelp are digested in hot water, the solution allowed to settle, and the clear liquor filtered. The residue is boiled two or three times with water, the fluid being filtered in each case, and the residue finally brought on a filter and washed with boiling water. The filtrates and washings are neutralized as nearly as possible with hydrochloric acid, and chlorine gas passed into the solution till the latter becomes of a distinct orange colour, due to the liberation of iodine and bromine.

The fluid is then shaken up with about one-fourth of its bulk of carbonic sulphide, which takes up the liberated iodine and bromine,

and carries them in solution to the bottom of the vessel, provided the specific gravity of the kelp solution be not higher than that of the carbonic sulphide. When this is not the case, the solution of kelp may be diluted till the carbonic sulphide sinks.

The bottom fluid, containing the iodine and bromine, is then drawn off by a fine syphon, and shaken up with an equal volume of water and some zinc filings. The solution is soon decolorized, on account of the formation of zinc iodide and zinc bromide, which pass into the water; and we have thus a watery solution of the two latter salts above, and colourless carbonic sulphide at the bottom. The latter is drawn off by a syphon, and restored to the kelp solution, to which some more chlorine-water is added; and, if a further quantity of iodine and bromine be liberated, the above operations are repeated till the liquor is quite exhausted.

It only now remains to evaporate the solution of zinc-salts, divide into three equal portions, and determine I, Br, and Cl, as before described.

With regard to the accuracy of the above method, it may be stated that two sets of trials on pure salts gave the following results, 5 grs. of each of the compounds being used in each case:—

5 grs. KI, 5 grs. KBr, and 5 grs. KCl, gave—

	Grains.
KI,	4·97
KBr,	4·97
KCl,	5·08

Another trial, with the same quantities, gave—

KI,	4·96
KBr,	4·95
KCl,	5·09

These results leave little doubt that the process is accurate and trustworthy, although I do not deny that other experiments are required to establish the method.

It will be observed that in any case where chlorine-water or gas requires to be used for concentrating the iodine and bromine, the amount of chlorine originally present in the sample must be determined by another process.

X.—*On the Chemistry of Coal-smoke.* By MR. W. R. HUTTON.

Read before the Chemical Section, December 20, 1869.

(*Abstract.*)

THE author glanced at the subject both in its sanitary and its economical aspects; and then, in order that the scientific principles involved in the prevention of smoke and in the complete utilization of the heating power of raw coal might be properly understood, he gave an analysis of best Wishaw coal,—one of the finest kinds of fuel in Scotland. It was as follows:—

Water,	2·8
Sulphur,	0·4
Volatile Matter,	36·9
Fixed Carbon,	56·3
Ash,	3·6
	100·0

VOLATILE MATTER.

Carbon,	14·0
Hydrogen,	6·0
Oxygen,	15·9
Nitrogen,	1·0
	36·9

In the ordinary combustion of coal, black smoke, and therefore soot, is only producible from the volatile matter of the coal, the fixed carbon, ash, &c., being incapable of generating smoke. The value of a fuel as a generator of heat is estimated according to the amount of carbon and hydrogen present in it. As ordinarily used, coal, during its combustion, gives rise to many curious compounds, including carbonic oxide, carbonic acid, watery vapour, ammonia, sulphurous and sulphuric acids, and various hydrocarbons, some of the paraffin series, and others of the naphthalin series; and, as they are volatile when liberated, they rise into the atmosphere and form the mixture known as coal-smoke. This material differs in its properties and composition, according to the composition and mode

of burning the coal; but in all cases sooty carbon and moisture are abundant, the former especially so in black smoke. But black smoke is soot, and is the result of the imperfect combustion of the coal, and even of its wasteful use. Mr. Hutton then went on to examine soot in its chemical aspects, and explained in detail how the difference of temperature in a furnace or domestic fire regulates the composition of the volatile matters of soot. The composition of London and Glasgow soot was shewn in a table, of which the following is a copy:—

Analysis of Soot.

	London.	Glasgow.
Carbon,	53·18	35·7
Tar and Oil,	18·00	15·0
Ammonia,	1·75	2·8
Potash,	0·20	0·3
Soda,	0·34	0·3
Lime,	1·00	0·8
Magnesia,	0·30	Trace.
Phosphate of Lime and Alumina,	2·08	3·2
Iron,	0·40	0·7
Sulphuric Acid,	4·60	7·9
Chlorine,	Trace.	0·4
Sulphocyanogen,	0·25	None.
Carbonic Acid,	0·70	Trace.
Sand,	14·40	25·7
Water,	2·80	7·2
	100·00	100·0

The author said he could guarantee the genuineness of the sample of London soot; but he was afraid that the Glasgow soot which he had examined was adulterated, judging by the large percentage of sand and water contained in it. The large proportion of sulphuric acid might be accounted for by the sulphurous quality of the Scotch coal, and by the great number of chemical works in Glasgow. Genuine Glasgow soot ought to contain a larger amount of ammonia: both samples were distinctly acid. While referring to the various uses of soot, Mr. Hutton mentioned that a considerable quantity was recently shipped to the West Indies, to be used there for the growth of the sugar-cane. The price is from 30*s*. to 40*s*. per ton. Considering that soot rarely contains less than about one-sixth of its weight of hydrocarbon compounds, the author of the paper proceeded to look at the production of soot from a commercial point of view, and asked if the value of soot is proportionate to the evils resulting

from the production of the material. Not more than 500 tons are gathered in Glasgow per annum, and the value never exceeds £1,000. Taking the waste of fuel, the loss of the nitrogen of the coal, the destruction of property, and the personal discomfort resulting from smoke and soot, he found that there was no profit, but rather a great loss instead. As a practical solution of the "smoke nuisance," Mr. Hutton briefly sketched a plan by which practically smokeless fires might be obtained, while all the volatile compounds could be separately collected, and be got in a form fit for utilization. He would distil the coal before burning, stopping short the process of distillation at such a stage as would permit *soft coke* to be formed—that is, fixed carbon with a sufficient amount of volatile matter in it to render it slightly inflammable. The other useful products would be chiefly crude oil, coal-gas, and ammonia. Assuming, as a basis of calculation, 2,000 tons of coal to be used daily, that amount would yield, in round numbers—

Soft Coke, ...	1,400 tons.
Crude Oil, ...	40,000 gallons.
Ammoniacal Water, ...	30,000 ,,
Coal Gas, ...	6,000,000 cubic feet.

Deducting the ash, the fixed carbon would be reduced to 1,329 tons. Mr. Hutton calculated that the coke and the other products would realize £742, while the coal (at 5*s.* per ton) and the labour, &c., would cost £600, leaving an apparent balance of £142, in addition to all the other advantages which would result from the complete combustion of the fuel. The coke would be such a material as would be available alike for domestic fire-places and the furnaces of steam-boilers, &c.

At the conclusion of the paper, various members spoke in commendation of Mr. Hutton's views. In reply to Mr. Stanford,

Mr. Hutton stated that such coke as he had suggested in his paper could be burned in the ordinary grate, without the expense or any other of the inconveniences attending the use of the grate which was devised some years ago by the late Dr. Neil Arnott.

On the motion of the Chairman, a cordial vote of thanks was awarded to Mr. Hutton; and the meetings of the Section were adjourned for a month.

XI.—*On Artificial Alizarine.* By Mr. J. Wallace Young.

Read before the Chemical Section, January 17, 1870.

The author first referred to the great importance of madder root in dyeing and calico printing, and to the numerous investigations made on it by different chemists. Of the various colouring matters obtained from it, alizarine was the most important, and gave all the well-known durable and brilliant colours yielded by the madder root itself. Owing to the high price of madder, great interest attaches to any substance purporting to be a substitute for it. M. Roussin thought he had obtained it from naphthalin, but further investigation proved him to have been mistaken. More recently its synthesis had been successfully accomplished by Messrs. Graebe and Leiberman from anthracen.

The author then stated the results of his experiments on two different specimens of the artificial alizarine. The first, of Continental manufacture, contained a good deal of colouring matter, which appeared to be absorbed readily enough by mordanted cloth; but on treating with solution of soap, the colours were found to be rather fugitive. When the artificial substance was subjected to heat, a sublimate was obtained closely resembling natural alizarine. This dyed mordanted cloth well, and withstood treatment with soap. The other sample of artificial alizarine, made by Messrs. Perkin & Sons, was a very different article. It is supplied in the form of an opaque brownish liquid; it dyes up mordanted cloth readily, the soaping, finishing, &c., being carried out in a precisely similar manner to madder work. On comparing the colours given by madder, against those of the artificial alizarine, we find the red of the latter to be rather yellower in shade, the black equal or superior, but the most marked difference is in the purple, which is rather a slate than anything else, and contrasts unfavourably with the fine madder purple. With Turkey-red prepared cloth and yarn, the colouring matter is readily taken up, and gives a good bright shade, but much yellower than madder or garancine; and the yellowness appears to be increased by the tin salt used in cleaning. As with madder and its preparations, the development of the colouring matter of the artificial alizarine is increased by tanning materials, and

deteriorated by the addition of chalk. The artificial alizarine was treated in various ways, such as boiling with dilute sulphuric acid, dissolving in sodium carbonate, and reprecipitating, &c., to see if the colours given by it were modified in any way; but no difference was observed. The colours given by the artificial alizarine stand well all the treatment usually given to madder goods; and on exposure to light for two or three months, no difference was observed between them. However, if we take pieces of cloth dyed with the artificial alizarine, and madder roots, and immerse them both together in a not overly strong solution of bleaching powder, and allow them to remain an hour or two, we shall find that the madder one has become lighter, still retaining its fine red colour, whereas the other one has become of a tawny yellow. On washing and soaping, the madder one was deepened in colour, and the other had almost disappeared.

The general effect of chalk on the artificial substance is to blue all the shades. The chocolates and reds are considerably altered in tone, and materially deteriorated, the purple is scarcely altered, but, strange to say, the black is much improved. The effect of chalk on alizarine or madder is to deteriorate all the colours. This artificial alizarine also yielded crystals, on sublimation, yellower in shade than the natural substance. Sometimes light yellow crystals were observed, which did not dissolve in sodium carbonate with the usual purple colour; they were soluble in boiling alcohol, and deposited on cooling. More or less of these crystals appeared to be produced according to the way in which the heat was applied in sublimation.*

Experiments were made with the sublimed product from the foreign and English artificial alizarine, and also with sublimed natural alizarine and purpurine. Mordanted cloth was dyed with each of these, and afterwards boiled with soap. The artificial alizarine gave a yellowish red, much like the purpurine, and differing from the dark full red given by the natural substance. The purple is a slate, but the chocolate and black do not differ materially. The purpurine, again, differs in giving scarcely any purple.

When the crystals were dissolved in ammonia, and barium chloride added, the natural alizarine gave a fine bluish-purple precipitate, the purpurine a purplish-red precipitate, the supernatant liquor being in both cases quite clear. The artificial substance gave a reddish-purple precipitate, the supernatant liquid

* Mr. Perkin, F.R.S., pointed out to the author that these crystals consisted of anthraquinone.

being highly coloured. On decanting off the liquors, and adding cold water, and repeating this two or three times, the natural alizarine and purpurine precipitates did not seem to be much affected, but the artificial alizarine precipitate gradually dissolved in the washing water, and finally disappeared.

An alum solution of the artificial alizarine gave, in the spectroscope, none of the bands characteristic of purpurine.

From the papers which have appeared in the *Chemical News*, and elsewhere, it would appear that the manufacture of artificial alizarine is carried out in two or three different ways by Continental chemists, and that some of the products appear to consist of a mixture of alizarine and purpurine in different proportions, and some of alizarine, or of a substance between the two.

From many experiments carried out practically, the author was of opinion that the artificial substance differed from the natural product, although closely resembling it in many of its properties.

It would be as yet premature to give any definite statement with regard to the real value of the artificial alizarine. It has been shewn that the tone of colours given by it differs materially in the purple, and also does not give good pinks, being far too yellow. But it is well known to those engaged in dyeing operations, that with madder and its different preparations, the tone of colour, and also the relative fastness, varies considerably, some being better suited for purple dyeing, and others for pinks. As far as can be seen at present, it may supersede madder for some things, if price permits; but no doubt, through course of time, the manufacture will be improved, and the substance cheapened.

XII.—*Notes of Experiments on Artificial Alizarine.* By Mr. John Christie.

Read before the Chemical Section, January 31, 1870.

The experiments described in the following paper were undertaken with the view of ascertaining the relation between the artificial alizarine, prepared from anthracene, to the pure alizarine of madder.

I have experimented for some time with the artificial alizarine of

MM. Lucius & Co., which gave 9·15 per cent. solid matter, when dried at 211° Fahr., and with that of W. H. Perkin, which gave 5·3 per cent., dried at 212° Fahr. I dyed swatches of calico, printed with stripes, for pink, red, purple, and chocolate, taking 100 parts by weight of cloth as a basis.

No. 1 was dyed with ·7 per cent. natural alizarine, sublimed.
No. 2 do. 1·4 per cent. Perkin's artificial alizarine, sublimed.
No. 3 do. 1·25 per cent. natural alizarine, sublimed.
No. 4 do. 1·4 per cent. = ·7 per cent. natural and ·7 per cent. artificial alizarine, sublimed.
No. 5 do. Perkin's fluid, 31·2 per cent. = 1·65 per cent. dried, as supplied to consumers.
No. 6 do. MM. Lucius' paste, 18·0 per cent. = 1·65 per cent. dried, as supplied to consumers.

When dyed, the white of No. 6 was worst, No. 2 better, the others all good, but alizarine No. 3 best. When soaped, the whites were all good, No. 3 deepest and best colours, No. 5 next; Nos. 1 and 2 were about equal in depth; No. 6 weakest in colours of pink bands, and lilac bad.

I had swatches of the series washed in weak soap-water daily for fifteen days, and exposed to the weather for two hours each day. Nos. 1 and 3, no perceptible reduction in any of the colours; No. 2, lighter in all the colours; No. 4, reduced a little in all the colours but lilac, which is slightly improved; No. 5, considerably lighter in all the colours; No. 6, much reduced, the pink to a mere flesh colour, and the lilac to a lavender shade.

On Turkey-red mordanted cloth swatches were dyed in the following proportions, taking 100 parts by weight of cloth as a standard:—

No. 1 was dyed with ·9 per cent. natural alizarine, sublimed.
No. 2 do. 1·75 per cent. Perkin's artificial alizarine, sublimed.
No. 3 do. 1·75 per cent. natural alizarine, sublimed.
No. 4 do. 25·4 per cent. paste = 2·32 per cent. dried, of MM. Lucius & Co.'s artificial alizarine.
No. 5 do. 43·7 per cent. fluid = 2·32 per cent. dried, of W. H. Perkin's artificial alizarine.

The process of clearing improved much the shade of Nos. 1 and

3; No. 2 about equal in shade to No. 1; it also withstood the clearing better than Nos. 4 and 5. These last numbers lost much in clearing, and the shade produced was far too yellow, and had no lustre.

When treated with concentrated sulphuric acid, both artificial and natural dissolve with a red colour: the natural has less of a rose tint than the artificial. Water precipitates the natural of a beautiful golden yellow colour, in granular flakes. Perkin's artificial, with water, also golden yellow, but the precipitate more gelatinous than was the natural; while MM. Lucius & Co.'s, with water, gave a brown yellow precipitate, having a slight green tinge. On filtering these solutions, the filtrate from the natural was colourless; Perkin's artificial, deep straw-colour; MM. Lucius & Co., light straw-colour. On addition of strong caustic soda, till the filtrates were alkaline, the natural took a very slight tinge of blue violet, while both artificial colours became a deep crimson, in which flakes of a beautiful crimson colour settled to the bottom, after twelve hours.

On subliming natural alizarine, prepared from the finest garancine, by boiling alcohol, distilling the alcohol off, and drying the residue at 212° F., I found it began to paste at 300° F., was fluid at 320° F., sublimed freely at 340° F. If the temperature be raised higher than 370° F., the action seems to be so violent that the points of the needles were coated with the matter in the state of fusion. If, however, the temperature be kept at 340° F., it will sublime with very little residue, and the crystals be quite clean. The fused matter had an action on the copper vessel used for sublimation.

On heating artificial alizarine, dried and powdered, to 340° F., I could not obtain a sublimate,—an orange-coloured efflorescence lay on the surface of the brown powder that had been placed in the vessel. I could not get a sublimate till the temperature was raised to 420° F., when I obtained very fine needles of a yellow colour, with a red tinge. The temperature raised to 450° F., and maintained at that point, I obtained from 100 parts of the dried powder 15 per cent. of a sublimate, at the end of one hour from applying the heat. I could not obtain more sublimate from the matter operated upon, which had not yet fused, but remained in a dry powder as when introduced. The temperature was now slowly raised, keeping a constant watch for the fusing point, or a further sublimate; but to 600° F.—the range of the thermometer employed—the matter did not fuse, nor did it yield further sublimate. It became, however, of a brown black, and on its surface lay a cake of orange-red crystals,

which possess colouring properties different from the sublimate at 450° F. (it yielded orange instead of red and pink; the chocolate, a yellow brown; the lilac, as good as the original fluid), although the matter does not fuse at 600° F. At that temperature I found a quantity of the colourless needles, mentioned by Mr. W. Young at last meeting, and also observed that the matter under treatment had acted on the copper vessel employed to sublime it, and formed a compound of copper, which scaled off the vessel on cooling. The uppermost vessel employed for the alizarine to sublime upon, is concave on the bottom; and when covered with filtering paper, has a hollow space between the paper and the vessel itself, which vessel contains cold water. The natural did not pass through the paper into this cavity; but of the 15 per cent. sublimed from the artificial powder, 10·1 per cent. had passed through, while that next to the cold metal was light straw-coloured flocks. I could not observe crystals of any size in the cavity. A yellow buttery matter, like picric acid in colour, had condensed on the metal of the condenser. When wet with water, it has a strong acid reaction of a litmus paper, while the more fluid oily matter condensed on the metal. When crude natural alizarine was sublimed, it was quite neutral to test-paper, and had a much more agreeable smell than artificial had.

On boiling a quantity of artificial alizarine in a saturated solution of sulphate of alumina (by Strecker & Stenhouse's processes for the preparation of purpurine from madder root and munjeet), very little dissolved, the filtrate was a light yellow colour, on addition of a large quantity of hydrochloric acid. No precipitate is formed, as is the case when purpurine is dissolved in alum solution. This yellow colouring matter can be separated by ether. On spontaneous evaporation of the ethereal solution, a gold-coloured oily matter is obtained, which coloured caustic alkaline solution red-violet. From this experiment, which was so different in result from either madder or munjeet, when boiled in alum liquor, and also from the permanence of the colour in caustic alkali, in which re-agent the colour given by purpurine becomes colourless in a short time, I am of opinion there is no purpurine present in artificial alizarine.

On placing swatches dyed with artificial alizarine in solution of caustic soda, containing 30 grs. soda per gallon, the artificial of W. H. Perkins and MM. Lucius in a short time throw off deep crimson colour, which can be seen rising from the surface of the cloth, and flowing down the swatch, falling in streaks through the

liquor. This is not the case with alizarine (natural), or even with garancine, which remain colourless. This crimson colour can be separated by ether, after neutralizing with acid. The amount of colour given off from the dyed swatch in this re-agent leads me to the belief that a great proportion at least of the artificial alizarine colouring matter is not identical with natural alizarine; and what goes further to establish my opinion is, that, selecting the finest needles of artificial alizarine, and dyeing therewith, it has only half the depth of colour when well soaped, and that it becomes lighter when exposed to the weather and washing, which natural alizarine does not.

On dissolving sublimed natural and artificial alizarine in $H_2\ SO_4$, and adding 50 per cent. of its weight of KNO_3, allowing to rest for a few hours, diluting with water, washing and dyeing on mordanted cloth, the natural produced beautiful and fast colours of orange on the red and pink bands, a fine yellow brown on the chocolate, and lavender drab on the lilac bands; while the artificial gave an iron buff to the red and pink, and weak brown on the chocolate and lilac,—which, on soaping, are reduced to very light shades.

On treating sublimed natural and artificial alizarine with nitro-sulphuric acid, natural alizarine, when diluted with water, produced a reddish-yellow solution, with oily beads floating on the surface; while the artificial became yellow, with hard white particles floating about. In the *Bull. Chem. Soc. de Paris*, Dec., 1869, I observed that M. Alfraise has not obtained phthalic acid, when artificial alizarine was oxidized, which is produced by oxidation of natural alizarine, purpurine, munjistin, chloroxy-naphthalic, and naphthaline.

On distilling artificial alizarine, I obtained, at about 500° F., a distillate of white needles, which filled the neck of the retort; but on treating natural alizarine in the same way, with a solid matter in the neck, there came over oily particles of a sharp biting sensation on the tongue.

From the several experiments I have made with artificial alizarine, my opinion is, that although this article may be the best attempt that has yet been made to produce alizarine of madder by chemical means, I must observe that, in its present state, it is far from being identical with it.

XIII.—*Note on a Specimen of Shell Sand from the Island of Coll.* By MR. EDWARD C. C. STANFORD, F.C.S.

Read before the Chemical Section, February 14, 1870.

THE specimen presented the form of sandstone, and consisted principally of particles of marine shells agglutinated by the action of rain. It had the following composition:—

Carbonate of Lime,	68·50
Carbonate of Magnesia,	1·51
Silica (Sand),	25·69
Phosphates of Iron and Alumina,	2·00
Organic Matter,	2·30
	100·00

The author noticed that nearly all the outer Hebrides have large deposits of shell sand on their west coasts, and that it forms the very best material for reclaiming the peat mosses of these islands, as the mixture makes a good soil.

Good lime is also made from this sand by burning it with peat.

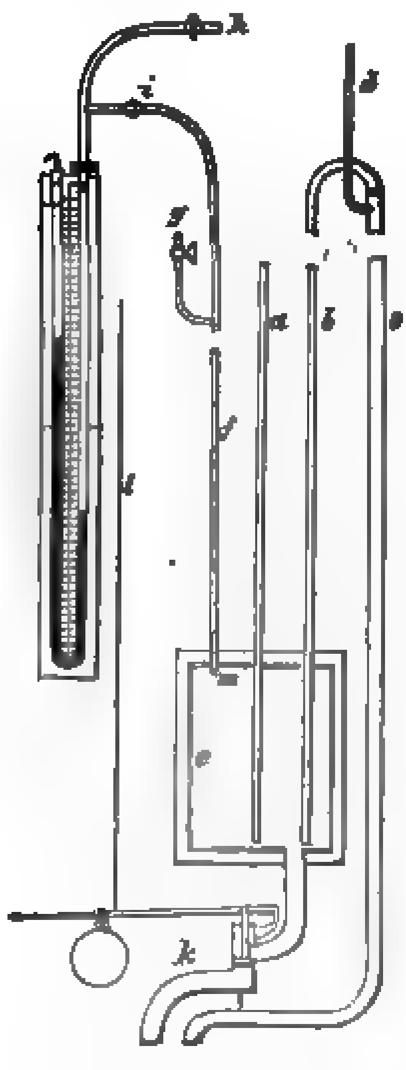
XIV.—*On a Method for obtaining a Continuous Current of Air or Gas under Pressure, for Blow-pipe or other Purposes.* By MR. T. L. PATTERSON, F.C.S.

Read before the Chemical Section, March 28, 1870.

THIS method is based on the same principle as the Catalan blow-pipe of Sprengel, and is wrought in connection with a Bunsen filter-pump, though it may be erected separately. It is well adapted to blow-pipe work, and a pressure, equal almost to half an atmosphere, may be obtained.

When the air-tap of a Bunsen pump is opened, and the water

turned on, air passes with the water down the exhaust-pipe to a depth of 30 or 35 feet, in a continuous stream of bubbles. If, now, instead of allowing this stream to pass into the sewer, we receive it in a bottle or other vessel made air-tight with a cork, through which two tubes are passed, one nearly to the bottom of the vessel, and the other just through the cork, water will flow off by the deep tube, and air escape by the upper; and by placing a stop-cock on the latter tube, to regulate the escape of air, the pressure in the vessel will be equal to the height of the water in the water-tube. The arrangement of the apparatus is shewn in the following figure. The water-pipes are ½ inch and the air-pipes ¼ inch internal diameter.



The exhaust-pipe of the pump, *a*, enters to within ¾ inch of the bottom of a leaden vessel, *e*, 9 inches square and 1 foot high. This vessel, or *accumulator*, is inclosed in a wooden box to support the sides and strengthen it, and has two holes pierced in the top at opposite corners. Through one the water-pipe, *b*, is passed to within ¾ inch of the bottom, and soldered air-tight. This pipe is carried up alongside of the other as many feet as may be desired (depending upon the pressure wanted), and then bent back and soldered into a 1 inch pipe, *c*, which returns and carries the overflow water from the pressure-pipe, *b*, to the sewer. It is necessary to attach a piece of ¼ inch pipe, *d*, to the 1 inch at the bend, *c*, so that the latter may not act as a syphon. Into the other hole of the leaden vessel, *e*, a piece of compo-pipe, *f*, long enough to reach to the laboratory, is soldered air-tight. One or more stop-cocks, as at *g*, may be taken off the pipe, *f*, to convenient places in the laboratory, and the pipe continued to the same manometer as is used to show the vacuum obtained by the pump. Just before the vacuum and pressure-pipes unite, however, there is a cock soldered into each; so that when the pump is working, the vacuum-cock, *h*, is open, and the pressure-cock, *i*, is shut, the reverse being the case when the pressure apparatus is required. The mercury in the manometer gives the vacuum or pressure in millimètres.

Beneath the vessel, *e*, is placed a lever stop-cock, *k*, of 1 inch diameter, to give free exit to the water while the pump is being worked for a full vacuum. This cock is wrought by means of a wire, *l*, over pulleys; and thus, when the water-tap is in the laboratory, the whole apparatus is under the control of the operator. Suppose, now, we want to work the pump, it is simply necessary to open the lever-cock below the accumulator, adjust the cocks, *h* and *i*, turn on the water, and the mercury in the near limb of the U tube will rise and indicate a vacuum. Then, when pressure is wanted, as for a blow-pipe jet, the lever-cock is closed, the air-pipe of the pump gently opened, the cocks, *h* and *i*, gently reversed to shew pressure by the manometer, and when the mercury has risen to its greatest height, the air is turned on to the blow-pipe, the flame of which will be maintained perfectly regular as long as water and air flow down the exhaust-tube. The adjustment for the flow of water is the same for the pressure as for the vacuum apparatus.

In my apparatus the water-pipe rises to a height of 13½ feet, equal to a column of mercury 303·6 millimètres, or 11·95 inches; but I have no doubt the apparatus will work well up to half an atmosphere, or probably more, if the tubes could be indefinitely lengthened; for the volume of air delivered in a given time varies with the difference between the lengths of the exhaust and pressure-pipes. A liquid may be boiled under the constant pressure of the apparatus by placing it in a strong flask, and connecting the latter, air-tight, by means of a flexible tube with the pressure stop-cock; or it may be distilled by connecting the receiver, made air-tight, to the retort or distilling vessel with the pressure stop-cock, as before. It will also be found useful for increasing filtration, by applying the pressure on the surface of the liquid to be filtered, when it is not desirable to use, or convenient to obtain, suction from beneath. But probably the most useful application of this air-current is to the blow-pipe. With a Herapath lamp, it is easy, by means of the stop-cocks, to obtain a small oxidizing or reducing flame suitable for chemical experiments, or the strong powerful jet for glass-blowing purposes and crucible operations. The power of this current is such, that with a Herapath lamp, consuming gas delivered from the main through an open stop-cock, under a pressure of 27 millimètres or so of water, the jet of air obtained is just sufficient to maintain a smokeless flame. When the apparatus is urged to its utmost, the water rises in the accumulator and enters the pipe, *f*; it is therefore advisable to have a float-valve at *m*, otherwise water might be projected into the flame.

Besides being suitable for obtaining a current of air, this apparatus will just as easily deliver a current of any other gas not very soluble in water. In which case, it is simply necessary to connect the stop-cock for admitting air with a vessel containing the required gas, open a pressure stop-cock, turn on the water, when the gas will be drawn in, and in the course of a few minutes displace the air in the apparatus. Experimenting with coal-gas in this way, I found it easy to obtain the sensitive flame of Tyndall and Barrett.

XV.—*On the Examination of Air.* By Dr. R. Angus Smith, F.R.S.

Read before the Chemical Section, April 25, 1870.

(Abstract.)

Dr. Angus Smith read a paper which had been read also to the medical officers of health in London. There were, however, portions which especially applied to Glasgow.

The object was to shew that it was now possible to examine air in such a way that we could say "this air is inferior and must not be breathed." This was done by examining the amount of solids, especially salts, as chlorides, sulphates, and nitrates, with the amount of acidity; next, the amount of ammonia, free or combined with acid; and lastly, the amount of albuminoid ammonia, or ammonia which was not liberated from its state without the action of caustic alkali—soda or potash, and permanganates at a boiling heat by Wanklyn's process.

The gradation of deterioration in town atmospheres was illustrated by tables. These tables shew that it is no longer purely a mysterious action of the atmosphere of which we must complain in large towns, but the action also of substances readily estimated by chemical means. They shew also the value of the chemist in sanitary matters. The purely medical man is not able to act without chemical aid.

The mode of making the experiments was simply by examining the washings of the air. The natural washings or rain were used in one set of experiments, and artificial washings of air in bottles were used for another class.

The amount of oxygen in the air of many places was also given. Here are added some of the tables.

RAIN.

AVERAGE TOTAL ACID OF CHLORINE AND SULPHUR, AND PROPORTION.

	Total Acid, free and combined.		Proportion of Hydrochloric to Sulphuric Acid.
	Grains per Gallon.	Parts per Million.	
England (inland country places),	0·6094	8·68	1 to 0·69
Scotland (sea coast and inland country places), . . .	0·7392	11·81	1 ,, 0·33
Germany, ...	1·2233	17·71	1 ,, 12·31
London, ...	1·5217	21·74	1 ,, 16·45
Darmstadt, ...	2·1098	30·14	1 ,, 29·98
St. Helens, ...	2·9902	42·72	1 ,, 3·48
Manchester, ...	3·3281	47·54	1 ,, 7·08
,, a^1, ...	4·0249	57·40	1 ,, 7·91
,, a_2, ...	3·1602	45·15	1 ,, 7·08
,, b, ...	3·0863	44·09	1 ,, 7·37
,, c, ...	1·8773	27·10	1 ,, 4·27
Runcorn, ...	3·4559	49·36	1 ,, 0·92

RAIN.

AVERAGE ACIDITY.

	Acidity, calculated as Sulphuric Acid, anhydrous.	
	Grains per Gallon.	Parts per Million.
England, ...	0	0
Scotland, ...	0·0200	0·285
Germany, ...	0·0894	1·273
Darmstadt, ...	0·1218	1·740
London, ...	0·2171	3·875
St. Helens, ...	0·2755	3·980
Manchester, ...	0·5833	8·330
,, a, ...	0·9696	13·850
,, a, from August, ...	0·5705	8·150
,, b, ...	0·1025	1·460
,, c, ...	0·1708	2·440
Runcorn, ...	0·7993	11·420

RAIN.

Ammonia.

	Parts per Million.
Scotland (inland and sea coast), ...	0·536
England (inland), ...	1·244
German specimens, ...	1·910
London, ...	3·450
St. Helens, ...	4·560
Runcorn, ...	4·630
Manchester, ...	5·350

RAIN.

Average Albuminoid Ammonia.

	Albuminoid Ammonia, parts per Million.
Scotland (sea coast and inland country places), . .	0·063
England (inland country places), ...	0·076
German specimens, ...	0·122
Runcorn, ...	0·190
London, ...	0·205
Manchester, ...	0·211
„ from August, ...	0·209
„ *a*, ...	0·216
„ *a*, from August, ...	0·180
„ *b*, ...	0·190
„ *c*, ...	0·250
St. Helens, ...	0·230

RAIN.

Average Nitric Acid.

	Nitric Acid, parts per Million.
Scotland, ...	0·256
Runcorn, ...	0·278
England, ...	0·578
London, ...	0·840
Manchester, ...	0·846
„ from August, ...	0·858
„ *a*, ...	0·810
„ *a*, from August, ...	0·667
„ *b*, ...	1·260
„ *c*, ...	0·648
St. Helens, ...	1·413
Germany, ...	2·890

AIR WASHINGS.—SUMMARY OF COMPARATIVE RESULTS.

AIR.

TOTAL ACID.

Relation to Blackpool taken as 100.

Blackpool,	100
London,	289
Didsbury,	315
Buxton,	333
St. Helens,	474
Manchester,	527
Underground Railway (Metropolitan),	1,483

AIR.

HYDROCHLORIC ACID.

Relation to Blackpool taken as 100.

Blackpool,	100
Buxton,	247
Didsbury,	277
London,	320
Manchester,	369
St. Helens,	516
Underground Railway (Metropolitan),	974

AIR.

SULPHURIC ACID.

Relation to Blackpool taken as 100.

Blackpool,	100
Didsbury,	320
Buxton,	345
London,	361
St. Helens,	468
Manchester,	549
Underground Railway (Metropolitan),	1,554

AIR.

TOTAL AMMONIA.

Relation to Innellan taken as 100.

Innellan,	100
London,	117
A Bedroom,	179
Glasgow,	202
Inside and outside of Office,	205
Underground Railway (Metropolitan),	235
A Midden,	398

AIR.

Ammonia.

Relation to Innellan taken as 100.

Innellan,	100
London,	117
Underground Railway (Metropolitan),	138
Glasgow,	159
A Bedroom,	194
Inside and outside of Office,	235
A Midden,	644

AIR.

Albuminoid Ammonia.

Relation to Innellan taken as 100.

Innellan,	100
London,	116
A Bedroom,	173
Inside and outside of Office,	194
Glasgow,	221
Underground Railway (Metropolitan),	271
A Midden,	302

The whole will appear in a forthcoming report.

MINUTES.

Corporation Buildings, November 3, 1869.

The Sixty-eighth Session of the Philosophical Society of Glasgow was opened this evening, in the Lecture Hall of the Corporation Buildings—Dr. James Bryce, the President, in the Chair.

The following gentlemen were elected members, viz.:—

Mr. Thomas Macdonald, Writer, 203 Hope Street; Mr. Nicol Brown, 136 West George Street; Mr. Robert Douie, Writer, 51 West Regent Street; Mr. James Smith, Writer, 21 Bath Street; Mr. J. S. Macgill, 2 Clifton Street; Mr. John Rankin, Commander of the Glasgow and Belfast Royal Mail Steamer, 257 St. Vincent Street.

The Society appointed Mr. James Reid and Mr. William Johnston to audit the Treasurer's Accounts.

The President delivered the annual address, which was occupied with an account of the life and labours of the late Mr. Thomas Graham, Master of the Mint, together with notices of deceased members of the Society.

On the motion of Dr. Francis H. Thomson, the thanks of the Society were voted to the President for his address.

Corporation Buildings, November 17, 1869.

The Society met this evening for the Sixty-eighth Annual Election of Office-bearers.

The following gentlemen were elected members, viz.:—

Bailie A. G. Macdonald, 8 Park Circus; Mr. James Miller, 21 Woodside Place; Mr. James Readman, 1 Kew Terrace; Mr. Alexander Drew, Calico Printer, 16 Hamilton Drive; Mr. William Caldwell Crawford, M.A., Eagle Foundry; Mr. James Marshall,

Ironfounder, 1 Royal Circus; Mr. John Sutherland, Soap Manufacturer, Kinning Park; Mr. William Paris, Glasgow Iron Works, St. Rollox; Mr. Robert Robson, Coalmaster, 12 Dixon Street; Mr. Robert Bain, Coalmaster, 22 Dundas Street; Mr. William M'Ewen, Jun., 11 Park Terrace; Mr. Robert M'Cowan, C.A., 87 St. Vincent Street.

The Secretary, Mr. W. Keddie, read the Annual Report by the Council on the State of the Society, which was approved of, and ordered to be printed in the next part of the Society's *Proceedings*.

Report by the Council on the State of the Society.

I. *The New Rooms.*—In their last Annual Report, the Council noticed the completion of the arrangement with the Town Council, for the accommodation of the Philosophical Society in the Corporation Buildings, Sauchiehall Street. The rooms, however, contrary to expectation, were not then ready for the reception of the Society and its Library; the books were therefore allowed to remain during winter and spring in the old Hall in Anderson's University; and by the courtesy of the Galleries Committee of the Town Council, the Society held its meetings throughout the session in the Gallery of Art. Early in the past summer, the Library was removed to the new room, under the superintendence of the Rev. Mr. Crosskey, the transference and arrangement of the books being one of his latest labours in Glasgow, previous to his departure for Birmingham. The Council, while acknowledging his great services to the Society on this occasion, avail themselves of the present opportunity of bearing their united and cordial testimony to the zeal evinced by Mr. Crosskey in discharging the duties of Librarian, to the intelligent and active interest he felt in enriching the collection by the addition of rare and valuable works, and to his perseverance and success in opening up an interchange of the Society's printed *Proceedings* with the publications of Universities and Scientific Societies abroad. The additional space afforded by the new book-cases is already to a large extent occupied. In the prospect of requiring a considerable accession to the present Library accommodation, by the union, as a Section of the Philosophical Society, of the Society of Architects, who will bring with them a fine and costly collection of illustrated books, the Council contemplate invoking the kind offices of their neighbours, the Institution of Engineers, whose room, contiguous to

the Society's Library, possesses ample space for the introduction of additional book-cases. In regard to the Library room, it only requires to be added that the completion of its furnishing is still retarded by the operations of workmen in adjoining parts of the premises.

With the nature and extent of the accommodation in the Lecture Hall, the Council, in common with the Society generally, cannot but feel grievously disappointed. The Council are still engaged, in co-operation with the Institution of Engineers, in negotiating with the Galleries Committee on the subject. The following extracts from the Minutes of Council shew that the question of the *kind* of accommodation, which has been raised since the opening of the session, was preceded by one which remains unsettled, as to the *extent* of it, in so far as concerns the possession of the Lecture Hall:—

"*October* 14.—The Secretary reported that he had attended a meeting of the Sub-committee of Town Council on Galleries, held in the Town Clerks' office on the 11th instant, and to which he had been invited by Bailie Macdonald, the Convener. He was requested by the Sub-committee to intimate to the Council of the Philosophical Society that the Galleries Committee were willing to allow the Society the use of the Lecture Hall eighteen nights during the winter, in virtue of the arrangement betwixt the Society and the Corporation, and for any further use of the Hall the Society to be charged £1, 1*s.* for each night.

"The Council expressed their dissatisfaction with this proposal, not having anticipated, in their arrangement with the Corporation, any limit to the necessary use of the Hall for Society and Sectional meetings, along with the Institution of Engineers in Scotland; and Professor W. J. Macquorn Rankine, as an office-bearer of the Institution, having made a similar statement as to the views of that body, it was suggested that the two Societies, through their respective Councils, should unite in insisting on their right to the use of the Hall, from October till May inclusive, on Monday, Tuesday, and Wednesday of each week,—the Tuesdays to be exclusively appropriated to the Institution of Engineers, the Mondays and Wednesdays to the Philosophical Society. The Council accordingly appointed the following members as a deputation to wait upon the Galleries Sub-committee of the Town Council, along with any deputation that may be nominated by the Institution of Engineers, to press their claim for the above arrangement, viz.:—Dr. Bryce, the President; Dr. Francis H. Thomson; Professor

Young, M.D.; Mr. St. John Vincent Day; Mr. William Macadam; the Secretary.

"*November* 3.—The deputation appointed to wait upon the Galleries Sub-committee reported that they had fulfilled their instructions, having at a meeting of the Sub-committee strongly urged the Society's claim. They were requested to transmit the claim to the Town Clerks in writing.

"*November* 10.—Great inconvenience and discomfort having been experienced at the first meeting of the Society this session, from the imperfect state of the Lecture Hall, in respect of seating, lighting, and ventilation,—and its capacity being inadequate to the accommodation of the present membership of the Society, leaving out of view what may be required by its prospective increase,—the Council is of opinion that the Hall does not afford 'suitable accommodation,' which the Corporation undertook to provide for the Philosophical Society when it agreed to become a tenant of the Corporation. The Council is further of opinion that it will not be for the interest of the Society to continue in possession of the Rooms, unless the agreement as to 'suitable accommodation' be fully implemented."

II. *The Sanitary and Social Economy Section.*—The members of the Sewage Association joined the Society as a Section, under this title, on the 27th of January. To the Section was remitted the consideration of the question of the removal or utilizing of the City Sewage, which had occupied the attention of the Society at three successive meetings. These discussions gave rise to much public interest. The Section embraces a considerable number of members of the Society, with a fair share of associate members, who pay a small annual fee. The meetings, as in the case of other Sections, are open to all the members of the Society.

III. *The Proceedings.*—The printed *Proceedings* of Session 1868-69 formed the first number of the Seventh Volume, and, including the Minutes and list of recent Donations to the Library, occupied 136 pages. The opening address of Dr. Francis H. Thomson, the President, treated on a variety of topics of practical importance, including Mr. Tall's method of constructing cheap dwellings for the poor, Mr. Ransome's patented process for making artificial stone, Nobel's application of dynamite as a blasting agent, petroleum and other substances used for fuel, the utilization of sewage, &c.

The Society was indebted to the Chemical Section for the following contributions to the *Proceedings*:—" On the Chemistry of Sugar

Manufacture and Sugar Refining," by Dr. Wallace; "On the Methods and recent Progress of Spectrum Analysis," by Professor Herschel; "On the Examination of the Flame of the Bessemer Converter," by Mr. Thomas Rowan; "On the Igniting Point of the Vapours of some Commercial Products," by Mr. W. R. Hutton; "A Chemist's View of the Sewage Question," by Mr. Edward C. C. Stanford; "The Salt Deposits at Stassfurt," by Messrs. J. H. Bald and James Mactear. Mr. Edward Hull, District Surveyor of the Geological Survey of Scotland, and since promoted to the head of the Survey in Ireland, made a communication to the Society "On the Extension of the Coal Fields of England beneath the recent Geological Formations." Mr. St. John Vincent Day read a paper "On the Sun's Distance and Parallax." The Rev. Henry W. Crosskey gave an account of "Recent Researches into the Post-tertiary Geology of Scotland." Professor Grant read a paper "On the Physical Constitution of the Sun, as revealed by the Phenomena of Solar Eclipses." To Dr. Grant's discourse, Sir William Thomson added some remarks on the origin and age of the Sun's heat.

The following additional communications were not printed in the *Proceedings*:—Sir William Thomson shewed some of Koenig's experiments illustrating vibrations of sound by means of flames, together with an instrument contrived by Helmholtz for indicating the number of vibrations. Dr. Allen Thomson read a paper "On the Minute Structure, Development, and Comparative Anatomy of the Retina." Mr. James Thomson read "Notes on the Structure, Stratigraphical Position, and Preservation of certain Carboniferous Fossils." The *Proceedings* ought to have been issued early in July; but the publication was delayed for upwards of a month, awaiting the manuscript of one of the communications.

IV. *State of the Membership.*—The Treasurer reports the largest accession to the number of members that has ever occurred in any one year since the foundation of the Society. At the commencement of the session the members on the roll were 286, and 96 were added in the course of the session. The number in the printed list is 369, to which add 6 new members admitted, and 12 elected this evening, and the total membership is 387.

The Librarian, Rev. H. W. Crosskey, reported on the state of the Library. The Report was approved of, and ordered to be printed in the next part of the Society's *Proceedings*. Mr. Crosskey, on retiring from the office of Librarian, received a cordial vote of thanks from the Society for his services.

Report of Librarian on the State of the Library.

In the removal of the Library, the Librarian had to make the best of the accommodation obtained from the Corporation, which fell far short of his expectations and the requirements of the Library.

It is greatly to the regret of your Librarian that he is compelled, by change of residence, to retire from office at a period in the history of the Library when the opportunity offers itself for carrying out more fully the plans he has for some years had at heart; although he can congratulate his successor on the good work before him.

It has been your Librarian's great object, not to purchase merely ephemeral publications, or books which have only a passing interest, but to obtain those standard works often beyond the private means of a large number of scientific students, but essential to the right direction of their researches—to make the Library a complete Reference Library for the great departments of science.

He has endeavoured to distribute the funds at his disposal fairly among different subjects, and each year to add some great works in each of the large departments of knowledge. Such a plan can only be judged over a series of years; because works have to be obtained as they enter the market, and blanks filled up as opportunities occur.

Your Librarian has also organized a series of exchanges with the learned Societies of Europe and America; and would offer the thanks of the Philosophical Society of Glasgow to those various bodies which have entered into courteous relationship with it.

Regular exchanges are now made with the following learned Societies:—Royal Institution of Great Britain; Geological Survey of India; Royal Geographical Society of Vienna; Royal Society of Victoria; Royal Academy of Belgium; Smithsonian Institution; Boston Natural History Society; Lyceum of Natural History, New York; Academy of Sciences, Philadelphia; Portland Natural History Society; St. Louis Academy of Science; Manchester Philosophical Society; Cambridge Philosophical Society; Leeds Philosophical Society; Liverpool Philosophical Society; Liverpool Geological Society; Edinburgh Botanical Society; Royal Society of Edinburgh; Historical Society of Lancashire and Cheshire; Geological Society of the West Riding of Yorkshire; Royal Academy of Sciences, Berlin; University of Christiania; Royal Institute of

Lombardy; Royal Scottish Society of Arts; Society of Arts, London; Institution of Engineers in Scotland; Glasgow Geological Society; Glasgow Natural History Society; Institution of Mechanical Engineers; Chemical Society of London; Chemical Society of Paris; Pharmaceutical Society; Bristol Naturalists' Society; Berwickshire Naturalists' Club; Woolhope Club; Scottish Meteorological Society; Anthropological Society of London; Royal Institution of Cornwall; Bath Natural History Society; Royal Society of Dublin; United States Patent Office; Patent Office, London; Cotteswald Naturalists' Field Club; Royal Physical Society of Edinburgh; Bombay Branch of the Royal Asiatic Society; American Philosophical Society; National Academy of Sciences, Washington; Royal Academy of Sciences, Amsterdam.

Upon undertaking the office (1866), your Librarian found fifteen volumes wanting, and three parts of Sowerby's *Botany*. These have all been discovered, except—Brewster's *More Worlds than One;* Mantell's *Wonders of Geology*, vol. i.; *Physico-Mechanical Experiments*, by R. Boyle; Hume *On the Steam Engine.*

A number of books, of which only imperfect sets were in possession of the Society, have been completed:—*Proceedings of Royal Society;* Cuvier and Valencienne's *Histoire Naturelle des Poissons* (vols. xvi. to xxii. obtained); *Proceedings of the Royal Society of Edinburgh*, completed; Sowerby's *Botany; Geological Magazine; British Association of Arts and Sciences; Palæontological Society, Publications of; Royal Agricultural Society of England; Journal of Statistical Society.*

The only imperfect sets we now have are—*Geological Transactions; Memoirs of the Geological Survey of Great Britain and Canada; Proceedings* of a few local Societies, chiefly out of print; *Royal Geographical Society's Journal*, the wanting volumes of which have been ordered.

Having left the imperfect geological works to the last, your Librarian trusts that his management will be seen to have been free from any attempt to give undue prominence to personal tastes.

Provision for the Sections.—Your Librarian has purchased all the books recommended by the Chemical and Sanitary Sections; and would suggest the propriety of a liberal dealing with the Sections in the management of the Library.

The following periodicals, formerly purchased, are now obtained without cost:—*Journal of Society of Arts; Chemical News; Pharmaceutical Journal.*

In Binding, large arrears have been gradually overtaken. Since 1866, upwards of 200 volumes have been bound. The periodicals are now duly bound up to their current years.

During the past year 381 volumes have been added to the Library, making the total number of books 4,831. When your Librarian entered office, the Library contained 3,875 volumes; and he has had the satisfaction of adding, by gifts, purchases, and exchanges, 956 volumes to the Library.

In resigning office, he would express the great pleasure he has had in the discharge of its duties, and the hope that the interests of the Society have not suffered in his charge.

The following Report by the Treasurer, having been printed in the circular calling the meeting, was held as read:—

ABSTRACT OF TREASURER'S ACCOUNT. SESSION 1868-69.

DR.

1868.—*Nov.* 1.

To Balances forward—		
In Union Bank of Scotland,..................................	£0 3 4	
In Treasurer's hands,..	0 15 1¼	
		£0 18 5¼

1869.—*Oct.* 30.

To Entry Money and Dues from 96 New Members, at 42*s*.,.........		201 12 0
,, Annual Dues from 3 Original Members, at 5*s*., ...	£0 15 0	
,, Annual Dues from 1 Member for two years, ...	0 10 0	
,, Annual Dues from 233 Members, at 21*s*., ...	244 13 0	
,, Annual Dues from 6 Members, for two years, ...	12 12 0	
		258 10 0
,, Subscriptions towards Expense of Furnishing New Rooms,......		107 19 0
,, Chemical Section.—From 22 Associates, at 5*s*., ...	£5 10 0	
Minus Expenses,.....................	1 13 0	
		3 17 0
,, Sanitary Section.—13 Associates, at 5*s*.,...................	£3 5 0	
Minus Expenses,.....................	0 16 0	
		2 9 0
,, Institute of Engineers, for Year's Rent till Whitsunday, 1869, &c.,		20 11 8
,, Interest from Bank,..		0 16 7
		£596 13 8¼

Cr.

1869.—*Oct.* 30.

By Salaries and Wages,		£120 10 0
,, New Books, and Binding,	£89 6 7	
,, Printing *Proceedings*, Circulars, &c.,	105 15 8	
,, Delivery and Postage of Circulars,	29 0 10	
,, Diplomas and Stationery,	10 7 0	
		234 10 1
,, Rent of Room, Andersonian University, year till Whitsunday, 1869,		45 0 0
,, Fire Insurance, Gas, Coal, Water, &c.,		29 12 8
,, Subscriptions to Societies:—		
Ray Society,	£1 1 0	
Palæontographical Society,	1 1 0	
Royal Archæological Institute,	1 1 0	
		3 3 0
,, Cost of Fitting up New Rooms, &c.,		162 9 6
,, Balance—In Union Bank,	£0 16 7	
In Treasurer's hands,	0 11 10½	
		1 8 5½
		£596 13 8½

The Society then proceeded to the election of Office-bearers, who were appointed as follows:—

President.

James Bryce, M.A., LL.D., F.G.S.

Vice-Presidents.

Professor Allen Thomson, M.D., F.R.S.
Dr. Francis H. Thomson.

Librarian.

Mr. St. John Vincent Day, C.E., F.R.S.E.

Treasurer.

Mr. John Mann, C.A.

Secretary.

Mr. William Keddie, F.R.S.E.

Other Members of Council.

Mr. George Anderson, M.P.
Mr. Alex. S. Herschel, B.A.
Prof. John Young, M.D., F.R.S.E.
Mr. John Downie.
Mr. William Macadam.
Mr. Edward C. C. Stanford, F.C.S.
Mr. Moses Provan, C.A.
Mr. Sigismund Schuman.
Dr. J. G. Fleming.
Mr. James Napier, F.C.S.
Mr. Daniel Macnee, R.S.A.
Mr. Robert Gray.

Corporation Buildings, December 1, 1869.—*The* PRESIDENT *in the Chair.*

The Society met in the Central Hall of the Corporation Gallery of Art.

The following were elected members, viz.:—

Mr. John Millar Thomson, 3 College; Mr. John Ferguson, M.A., University Chemical Laboratory, 15 Shuttle Street; Mr. O. T. B. Gardner, Secretary, Paraffin Light Company, 3 West Princes Street; Mr. Ralph Lowe, Merchant, 52 Frederick Street, North; Mr. R. Ormiston, Insurance Broker, 135 Buchanan Street; Mr. Robert Leggat, Lithographer and Engraver, 63 West Cumberland Street; Mr. Alexander Gow, Clydesdale Dye Works, Rutherglen; Mr. Thomas Mann, Wholesale Stationer, 204 West Regent Street; Mr. Robert Gillies Lowndes, Manufacturer, Crosslie House, Thornliebank; Mr. W. B. Adamson, Manufacturer, 10 Stirling Road; Mr. James Scott, Oil and Colour Manufacturer, 89 Breadalbane Terrace, Garnethill; Dr. James Cowan Woodburn, 2 St. George's Road; Mr. Thomas Alexander, 8 Sardinia Terrace; Mr. Thomas Kennedy, 99 Bath Street; Dr. James M'Pherson, 115 Bath Street; Dr. Thomas Reid, 9 Elmbank Street; Mr. John Craig, 16 Abbotsford Place; Mr. Lewis M'Lellan, 26 India Street; Mr. James R. Macfadyen, Fellow of the Faculty of Actuaries of Scotland, City of Glasgow Life Assurance Company; Mr. William Collins, Publisher, 7 Hampton Court Terrace.

A paper on the subject of Patents for Inventions was read by MR. ST. JOHN VINCENT DAY, C.E.

The following motion was then proposed by Dr. Bryce, President, and seconded by Dr. Francis H. Thomson, Vice-President, viz.:—

"That this Society, while recognizing the benefits which have accrued to inventors, and to the public, from the operation of the new Patent Law, since the Amendment Act came into force, in 1852, considers that the law is in several respects defective; and, whilst pledging itself to use all the means in its power to oppose a total abolition of the law, will lend an earnest and active support to any well-devised scheme of amendment."

On the invitation of the President, Mr. Macfie, M.P. for the Leith Burghs, addressed the Society. Mr. Edward C. C. Stanford, Mr. Walter Montgomery Neilson, and Mr. Robertson, took part in the discussion,—the adjournment of which, till the next ordinary meeting, was moved by Mr. John Mayer.

Corporation Buildings, December 15, 1869.—*The* President *in the Chair.*

The following gentlemen were elected members, viz.:—

Professor Edward Caird, University of Glasgow; Mr. John Inglis Bruce, Drysalter, 33 Hope Street; Mr. J. J. Coleman, F.C.S., 266 Dumbarton Road; Mr. Robert Gourlay (Westlands, Laidlaw, & Co.), 10 Howard Street; Mr. William Walker, Merchant, 1 West Regent Street; Mr. James Morrison, Auctioneer, 102 Renfield Street; Mr. James Craig Arnot, Painter, 121 Douglas Street; Mr. Archibald Arrol, 16 Dixon Street; Mr. Thomas Kennedy, Jun., 3 North Exchange Court; Mr. Thomas S. Cree, 305 St. Vincent Street; Rev. John Page Hopps, Roselynn Villa, Queen's Park; Mr. James Walker M'Gregor, 46 Hill Street, Garnethill; Mr. John M'Kendrick, Engineer, Cranstonhill; Mr. William Garth Thomson, Merchant, 22 Lynedoch Street.

The adjourned discussion on Patents for Inventions was resumed by Mr. John Mayer, F.C.S. On the invitation of the President, Mr. Samuel Cunliffe Lister, inventor of the woolcombing machine, who had come from Bradford to be present, addressed the Society. He was followed by Mr. Edmund Hunt, who proposed the following resolutions:—

"1. In the opinion of this Society, the time has not arrived when the progress of the arts and manufactures in this country would be promoted by the abolition of Patents for Inventions.

"2. The seventeen years' experience of the Patent Law Amendment Act of 1852, whilst proving that it possesses important advantages, as compared with the system previously existing, has shewn that various great but remediable defects are associated with it, and the time has arrived for the introduction of an improved system of patents avoiding those defects.

"3. Any Parliamentary inquiry, instituted with a view to improved legislation, should be conducted so as to collect the fullest possible information from the various important manufacturing centres of the kingdom, and from all classes in any way concerned in inventions or patents."

The adjournment of the discussion was moved by Mr. J. G. Lawrie; and the Society agreed by a vote to hold a special meeting on Wednesday next, the 22d December, for the conclusion of the discussion.

Corporation Buildings, December 22, 1869.—*The* PRESIDENT *in the Chair.*

The Society held a special meeting, to continue the discussion on the Patent Laws.

The discussion was resumed by Mr. J. G. Lawrie, who was followed by Dr. Robert Bell, Mr. James Stirling, and Mr. James Anderson.

Mr. William R. W. Smith proposed, as an amendment on the motion of the President, "That in the opinion of this Society, from the progress of the arts and manufactures in this country, and the alteration in our trading relations with other countries, the time has arrived for a reconsideration of the Patent Laws." Seconded by Mr. John Mayer.

After some remarks by Mr. Walter M. Neilson, Mr. Day closed the discussion by speaking in reply.

The first motion having been withdrawn, and the first of Mr. Hunt's series of resolutions rejected by a majority of 16 to 12, the following resolutions, as embracing the spirit of Mr. Smith's and Mr. Hunt's motion, was proposed by the President, seconded by Dr. Francis H. Thomson, and unanimously agreed to:—

"1. That, in the opinion of this Society, the progress of the arts and manufactures in this country, and alterations in its trading relations with other countries, render necessary a reconsideration of the Patent Laws; and they would hail with satisfaction the appointment of a Royal Commission to collect information at the great manufacturing centres of the kingdom, as well as from all classes of persons in any way connected with inventions or patents.

"2. That for the purpose of observing the progress of legislation, and if necessary, preparing a petition or memorial in conformity with the resolution of the Society, the following gentlemen be appointed a Committee, with power to add to their number, viz.:—Dr. Bryce, President; Dr. Francis H. Thomson, Vice-President; Sir William Thomson; Dr. W. J. Macquorn Rankine; Mr. Walter Montgomery Neilson; Mr. Edward C. C. Stanford; Mr. J. G. Lawrie; Mr. John M. Rowan; Mr. W. Rae Wilson Smith; Mr. John Mayer; Mr. W. R. Hutton; Mr. James Anderson; Mr. James Robertson—Mr. Walter M. Neilson, Convener."

The Society then adjourned till the 12th of January.

Corporation Buildings, January 12, 1870.—*The* PRESIDENT *in the Chair.*

The Society met in the East Hall of the Upper Corporation Galleries.

The following were elected members, viz.:—

Mr. William R. Findlay, Manufacturer, 62 Queen Street; Mr. James A. R. Main, Manufacturer, 5 Renfield Street; Mr. Alexander Smith Baird, Merchant, 19 Sardinia Terrace, Hillhead; Mr. J. Boucher, Architect, 177 St. Vincent Street; Mr. Adam Gossman, 11 Winton Terrace, Victoria Road; Mr. Mathew Glassford, 71 West Cumberland Street; Mr. David Sandeman, Merchant, 3 Woodlands Terrace; Rev. James Stewart-Johnson, Manse, Cambuslang; Mr. James Baird, Manufacturing Chemist, 54 St. Vincent Street; Mr. Joseph Anthony Dixon, Writer, 146 West George Street; Mr. Archibald Stewart Byres, Chemist, 6 South Wellington Street; Mr. W. A. Stevenson, Merchant, 26 Granville Street; Mr. William Renny Watson, 16 Woodlands Terrace; Mr. William Ritchie, Jun., Calico Printer, Kincaidfield House, Milton of Campsie.

ARCHITECTURAL SECTION.

The Council of the Glasgow Architectural Society having made arrangements for a union of that body with the Philosophical Society, the following members of the Architectural Society were duly elected at last meeting, and are now declared to constitute the Architectural Section of the Philosophical Society, viz.:—

James Salmon, Architect, I.A., 141 West George Street; Alexander Thomson, Architect, I.A., 183 West George Street; J. Honeyman, Jun., Architect, I.A., 61 West Regent Street; James Howatt, Measurer, 146 Buchanan Street; *Campbell T. Bowie, Painter, 26 Bothwell Street; James Thomson, Architect, I.A., 61 West Regent Street; Mungo C. Duff, Measurer, 183 West George Street; James Steel, Plasterer, 25 Holmhead Street; William Maclean, Writer, 88 West Regent Street; Alexander Watt, Architect, 67 Renfield Street; Campbell Douglas, Architect, I.A., 266 St. Vincent Street; James Watson, Builder, 3 North Cumberland Street, Calton; James Adam, Architect, 154 George Street;

* Those having an asterisk attached to their names were previously Members of the Philosophical Society. Those having I.A. are Members of the Institute of Architects.

James Henderson, Architect, 193 St. Vincent Street; Alexander M'Auat, Slater, 27 St. Andrew's Lane; James Hamilton, Architect, 111 West Regent Street; J. Wilson, Builder, 468 Gallowgate; *Walter Macfarlane, Engineer, Saracen Foundry, 46 Washington Street; George Thomson, Architect, I.A., 183 West George Street; J. Shields, Jun., Measurer, 183 West George Street; J. M'Donald, Builder, Comley Park House; *Walter M. Neilson (Locomotive Works, Springburn), Hydepark; William Clarke, Architect, I.A., 37 West Nile Street; J. Mossman, Sculptor, 83 North Frederick Street; Thomas Russell, Saracen Foundry, 46 Washington Street; Thomas Lamb, Builder, 190 Parliamentary Road; *Angus Kennedy, Architect, I.A., 99 Bath Street; Charles Gray, Painter, 156 West George Street; *William Connell, Plumber, 108 Argyle Street; Henry Herbertson, Measurer, 137 West Regent Street; William Wilson, Builder, 740 Gallowgate; Robert M'Cord, Builder, 54 St. Enoch Square; Robert Ward, Builder, 19 Germiston Street; James Lamb, Surveyor and Valuator, 9 West Regent Street; J. Cannan, Agent, 243 Buchanan Street; *James Allan, Sen., 83 Bothwell Street; Alexander Smith, Slater, 20 Little Hamilton Street; J. M'Intyre, Wright, 317 Bath Street; Charles Malloch, Glass Merchant, 12 Croy Place; John J. Stevenson, Architect, I.A., 266 St. Vincent Street; J. Hay, Valuating Engineer, 110 Bothwell Street; J. Neilson, Builder, 301 St. Vincent Street; *James Stevenson, Jun., Yarn Merchant, 23 West Nile Street; *John Thomson, Potter, Annfield Pottery, 573 Gallowgate; *Alexander Harvey, Dyer, 4 South Wellington Place; Charles Carlton, Painter, 119 St. Vincent Street; John Gordon, Architect, I.A., 175 Hope Street; Henry Purnell, Heating and Ventilating Engineer, 305 Parliamentary Road; William Thomson, Modeller, 7 Chatham Place; Alexander Goldie, Bricklayer, 78 Rutherglen Loan; Robert Corbet, Brick-builder, 70 Fordneuk Street; James Connell, Joiner, 59 St. James Street, Kingston; Alexander Marshall, Joiner, 9 Havelock Street; George Laird, Wright, 10 Ann Street, Bridgeton; James Thomson, Messrs. Allan & Mann, 48 St. Enoch Square; Alexander Muir, Mason, 3 Abbotsford Place; Robert Baldie, Architect, I.A., 29 Bath Street; James Stewart, Slater, 48 Norfolk Street; Horatio K. Bromhead, Architect, I.A., 159 West George Street; George Smith, Ironfounder, 64 Port-Dundas Road; Daniel Cottier, Glass Painter, 130 West Graham Street; Robert G. Melvin, Architect, 124 St. Vincent Street; Robert Ramage, Painter, 61 Union Street; James Walker, Jun., Measurer, 175 West George Street; J. Cowan, Wright, 24 Dover Street; *William Gentles, Paperhanging Ware-

houseman, 10 Jamaica Street; William Forrest Salmon, Architect, I.A., 141 West George Street; William Howatt, Measurer, 146 Buchanan Street; Walter Tully Knox, 40 M'Kechnie Street; James Millar, Wright, 124 Parliamentary Road; John D. Thomson, Timber Merchant, 54 Jane Street; William Steven, Brickbuilder, 481 London Road.

The following motion was proposed by Mr. John Mayer, and seconded by Mr. Sigismund Schuman:—

"That the Council of the Philosophical Society be respectfully requested to make arrangements to have full reports taken of all discussions at the Society's meetings, and of such communications as are made orally to the Society."

After some discussion the motion was withdrawn in favour of a recommendation, which met with general concurrence, that the Council take the matter into consideration.

Dr. Francis H. Thomson reported on the part of the Council the result of recent negotiations with the Committee of Town Council, for the purpose of obtaining adequate accommodation for the general meetings of the Society. The Committee offered to the Society for its ordinary meetings the East Hall of the Upper Corporation Galleries, at an additional rent of £30 per annum, the Society being at the same time allowed the use of the Lecture Hall for its Sectional meetings, as under the former arrangement whereby the Society became the tenant of the Corporation. The Council, considering the necessity which had arisen, by the large influx of new members, for a greater amount of accommodation than was anticipated when the Society took possession of its rooms in the Corporation Buildings, agreed to recommend to the meeting this evening to accept of the offer made by the Committee of Town Council, stipulating, however, that the East Hall be rendered more comfortable and suitable for the meetings of the Society.

The recommendation of the Council was unanimously approved of.

Dr. Bryce, the President, read a paper "On the Geological Structure of Skye and the West Highlands."

Corporation Buildings, January 26, 1870.—*The* President *in the Chair.*

The following were elected members, viz.:—

Mr. William Swan, Shipbuilder, Maryhill; Mr. William A.

Smith, 2 North Court, Royal Exchange; Mr. William Foulis, Engineer, 42 Virginia Street; Mr. John Knox, 70 St. Vincent Street; Mr. Zechariah John Heys, Calico Printer, South Arthurlie, Barrhead; Mr. George Erskine Darling, 247 West George Street; Mr. Robert Mitchell, 113 Argyle Street.

Mr. James R. Macfadyen, Fellow of the Faculty of Actuaries of Scotland, read a paper "On the Scientific Principles affecting the Solvency of a Life Assurance Company, and the extent to which the Public can be protected against their Violation."

In the discussion which followed the reading of the paper, Mr. Anderson, M.P., Mr. Jeffrey, Mr. Prentice, Mr. Turnbull, Mr. Brown, Mr. Provan, and Mr. Marr, took part.

Corporation Buildings, February 9, 1870.—*The* President *in the Chair.*

The following were elected members, viz.:—

Mr. Joseph Campbell, Jun., Merchant, 80 Gordon Street; Mr. Charles Prentice, Actuary, 39 St. Vincent Place; Mr. John Hunter Jackson, 35 Carnarvon Street; Mr. James Reid, Engineer, Wellfield, Springburn.

Professor Young called attention to an inaccurate report of the proceedings of the Society on the 12th of January, which had been published in the periodical entitled *Nature*, on February 3. On the motion of the President, seconded by Mr. James Thomson, the Secretary was instructed to send a letter to the editor, disavowing the report as being "inaccurate and unauthorized."

The President mentioned that the Council had duly considered the Society's remit as to the reporting of its proceedings; and that, at the Council's request, the Secretary had undertaken to perform this duty.

It was also reported from the Council, by the President, that a committee of its members had been nominated to co-operate in any way competent to them with the North of England Institute of Engineers, on the occasion of their holding their annual meeting in Glasgow this year,—the invitation to the Philosophical Society to lend its assistance having been communicated through Professor W. J. Macquorn Rankine.

Dr. Gairdner delivered an address "On Defects of House Construction in Glasgow as a Cause of Mortality."

After some remarks by Mr. Morrison, the discussion was, on the motion of Mr. M'Adam, adjourned till next meeting.

Corporation Buildings, February 23, 1870.—*The* PRESIDENT *in the Chair.*

The following were elected members, viz.:—

Mr. Thomas Maclean, Merchant, 124 Queen Street; Mr. Alexander Mitchell, Jun., Manufacturer, 11 Wilton Crescent; Dr. John Clark, Andersonian University; Mr. George Bell, I.A., 37 West Nile Street; Dr. John M'Conville, 27 Elmbank Place; Mr. A. H. Maclean, Yarn Merchant, 124 Queen Street; Bailie Alexander Osborne, 5 Oakley Terrace, Dennistoun.

The discussion on Dr. Gairdner's communication, "On Defects of House Construction in Glasgow as a Cause of Mortality," was resumed by Mr. David G. Hoey, who was followed by Mr. Ure, Mr. Finlay, Mr. M'Intosh, Mr. Ramsay of Kildalton, Mr. Bromhead, and Mr. William R. W. Smith. The discussion then terminated.

Corporation Buildings, March 9, 1870.—*The* PRESIDENT *in the Chair.*

The following were elected members, viz.:—

Mr. John Young, Jun., Forth Street, Port-Dundas; Mr. James Fleming, Jun., Newlandsfield, Pollokshaws; Mr. James Alexander, Jun., Writer, 153 St. Vincent Street; Mr. David J. M'Goun, Drysalter, 7 Berkley Terrace.

The PRESIDENT mentioned that at present there was an extraordinary development of spots on the Sun, the dimensions of several of which he pointed out.

MR. WILLIAM WEST WATSON, City Chamberlain, read a paper entitled, "A Glance at some of the Vital and Social Statistics of Glasgow in 1869." In the discussion which followed, Dr. Gairdner, Dr. Bell, Dr. Lyon, Dr. Morton, Dr. Cowan, Mr. Macintosh, and others, took part.

Corporation Buildings, March 23, 1870.—*The* PRESIDENT *in the Chair.*

The following papers were read, viz. :—

MR. JOHN M. THOMSON,—"Notes upon the Appearance and Chemical Constitution of Ancient Glass found in Tombs in the Island of Cyprus."

MR. JOHN MAYER,—"On the recent Progress of the Iron Manufacture in Cleveland."

Corporation Buildings, April 13, 1870.—*The* PRESIDENT *in the Chair.*

The Society, on the recommendation of the Council, agreed to grant the sum of £5 to the fund now being collected for the relief of the family of the late Professor Sars of Christiania, Norway. The first vote was taken, and passed unanimously.

MR. PROVAN called attention to the insufficiency of the subscription by members of the Society to meet the expense incurred in removing from the former to the present rooms; and proposed that members who had not contributed for this purpose should be called upon by the collector for their subscriptions,—the call, however, not to be made upon those who have recently joined the Society.

PROFESSOR YOUNG, M.D., read an abstract of a paper "On the Definition of a 'Formation' in Geology." He sketched the gradual changes of meaning which the term had undergone, and remarked on the want of precision in the use of this and other phrases. He described at length the views of Austen, E. Forbes, Huxley, and Barraude, on the correlation of strata, and the arguments with which these views had been met. The object of the paper was to support the definition of a formation as a zoological province, and to shew that generalized geological sections are a fruitful source of misapprehension, and that the insertion in the list of strata in any country of so-called "missing strata" found elsewhere, is at variance with the principles established by Ramsay in his anniversary addresses to the Geological Society.

MR. JAMES THOMSON described the structural characteristics of the different species of Megalichthys, which he illustrated by a suite of specimens, and by sections under the microscope.

Corporation Buildings, April 27, 1870.—*The* PRESIDENT *in the Chair.*

On the assembling of the Society this evening, the PRESIDENT referred to the loss which it had sustained since the last meeting, by the death of Dr. Francis H. Thomson, one of the Vice-Presidents. The President, after making some suitable remarks on Dr. Thomson's character and attainments, and on his long and valuable services to the Society, moved that, out of respect to his memory, the Society do now adjourn for a week, and that the President and Secretary be instructed to prepare a minute expressive of the Society's sense of its loss, and of its sympathy with Dr. Thomson's widow in her bereavement.

Corporation Buildings, May 4, 1870.—*The* PRESIDENT *in the Chair.*

The SECRETARY read the following notice of the death of Dr. Thomson, which he was instructed to insert in the minutes, and communicate a copy of it to Mrs. Thomson:—

"The Philosophical Society avails itself of the earliest opportunity of expressing its profound sorrow for the loss it has sustained by the death of Dr. Francis Hay Thomson, one of its Vice-Presidents.

"Dr. Thomson's services to the Society commenced in 1846, when he took an active share in promoting the Exhibition of that year, especially in its department of the Fine Arts; and they terminated in his persevering and successful efforts to obtain from the Municipal Corporation a portion of the funds accruing from that Exhibition, to be applied to the present and future accommodation of the Society.

"He occupied the chair for a somewhat prolonged period—first as Vice-President (during a temporary vacancy), and afterwards as President; and throughout his term of office he evinced a zealous interest in all that pertained to the prosperity and progress of the Society. Only those who came most frequently in contact with him knew the amount of patient attention which he devoted to the Society, and how accessible he was at all times, when his advice and assistance were required in the management of its affairs.

"His intercourse with the members of Council was uniformly friendly, affable, and confiding; and all of them will miss his genial

and welcome presence, and feel the want of his practical sagacity and talent for business.

'On his attainments in art and science, the Society will have an opportunity of bearing testimony through an official channel, on a future and more befitting occasion. Suffice it meanwhile for the Society to record the simple utterance of its sincere regret for the loss of an efficient office-bearer, an accomplished member, and a true-hearted friend.

'The Society will not venture to intrude upon the sacredness of private and family sorrow beyond the expression of its respectful and affectionate sympathy with Dr. Thomson's widow, in a bereavement which has so suddenly blighted her fondest hopes of domestic happiness.'

The proposal to vote the sum of £5 from the funds of the Society, for the relief of the family of the late Professor Sars, was a second time submitted to the Society, and finally agreed to.

The following gentlemen were proposed as members, on the understanding that the ballot for their election will be taken at the first meeting in next session:—

Mr. James Anderson, Oil and Colour Merchant, 58 Hyde Park Street; Mr. Stephen Mason, Manufacturer, 47 Queen Street; Mr. Allan H. Maclellan, 6 Lansdowne Crescent; Mr. C. Buie Renshaw, Glenpatrick, by Paisley; Dr. William Greenlees, 11 Elmbank Street; Mr. Thomas Wilkinson Watson, 8 Grafton Place; Mr. John Rankine, Manager, Strathclyde Turkey-red Dye Works; Dr. A. Wood Smith, F.F.P.S.G., 6 Newton Terrace; Mr. James A. Wenley (Bank of Scotland), 8 Lynedoch Crescent; Mr. J. C. Wyper (Messrs. F. Orr & Sons); Mr. Robert A. Bryden, I.A., 34 Abbotsford Place; Mr. William Melvin, 89 South Portland Street; Dr. James Stewart, 6 Brandon Place; Mr. Alexander Fergusson, Treasurer, Caledonian Railway Company, 31 Elmbank Crescent; Mr. James Aspin, Varnish Manufacturer, 1 India Street, West; Mr. Archibald Nairn, Wright, 24 Cochran Street.

The following papers were read:—

Dr. Bryce,—"On a Group of Syenitic Rocks at Westfield, near Linlithgow," with remarks on the suitability of various rocks for harbour works and street materials.

Mr. W. Keddie,—"On China Grass (*Boehmeria nivea*), for the

preparation of which, by suitable machinery, the Government of India offers a prize of £5,000."

Mr. Robert R. Tatlock reported on the proceedings of the Chemical Section.

CHEMICAL SECTION.

The Council of the Section are glad to be able to report to the Society that everything connected with the working of the Section continues in a most satisfactory condition. There are now 61 associates who are not members of the parent Society; and the number would have been considerably greater, but for the fact that many of the associates have been led, on account of their connection with the Section, to see the advantages of joining the Philosophical Society, and have in consequence become members of that body.

Eleven meetings have been held during the present session, at which sixteen papers have been read; each paper having a special interest, and some of them based upon original researches. Short abstracts of these papers appeared at intervals in the *Chemical News*, a fuller report of the more important papers being reserved for the *Proceedings of the Philosophical Society.*

The following is a brief sketch of the proceedings of the Section:—

At the opening meeting, 8th November, 1869, Dr. Wallace, F.R.S.E., Vice-President, delivered the usual presidential address, in which he referred at great length to the progress of chemical science within the last few years, and also to the life and labours of the late Mr. Graham, Master of the Mint.

At the second meeting, the same gentleman gave an account of his experiments with the water of domestic cisterns, demonstrating that the fears which had been entertained regarding the danger of using such water for dietetic purposes were groundless.

At the next meeting, Mr. E. C. C. Stanford read a paper "On the Action of House Sewage on Lead Pipes," shewing that the pipes are frequently rapidly corroded by the sewage, and leakage of the contents caused thereby.

At the same meeting, Mr. R. R. Tatlock read a paper "On the Estimation of Iodine and Bromine," the method described being based on the fact that bromine replaces iodine, and chlorine replaces both.

At the fourth meeting, Mr. W. R. Hutton read a communication "On Coal-smoke." The author proposed, as a means of diminishing

smoke, to distil the coal to obtain a useful and saleable oil, and then to use the residual coke as fuel.

At the following meeting, a paper, "On Artificial Alizarine," was read by Mr. J. W. Young, embodying the results of numerous experiments made by the author on this new and important colouring matter; and on the evening of meeting thereafter, Mr. J. Christie followed with the same subject, treated in a most elaborate and exhaustive manner, and illustrated by numerous dyed specimens of cloth. The proceedings of these two evenings have excited the interest of several of the leading chemists of the country.

At the seventh meeting, Mr. A. Campbell, St. Rollox Chemical Works, read two contributions "On Californian Borax and Sicilian Sulphur." Mr. James Mahony then read a note "On the Ooze from the Atlantic Sea-bed, obtained during the Dredging Expedition of H.M.S. *Porcupine;*" which paper was followed by one from Mr. Stanford, "On Shell Sand from the Island of Coll."

Mr. Charles Smith, at the succeeding meeting, exhibited several pieces of Chemical and Electrical apparatus, of a kind seldom required in physical researches, explanations being given by Dr. Wallace.

On March 14, Mr. W. R. Hutton occupied the greater part of the evening with a description of Canadian Phosphate of Lime, and other phosphatic substances used in the manufacture of artificial manures. This was followed by a note from Mr. Mahony, "On Plate Sulphate of Potash."

At the next meeting, Mr. T. L. Patterson described a method of obtaining a continuous blast of air under pressure for blow-pipe and other purposes. The apparatus described was an ingenious adaptation of the principle of the Sprengel air-pump.

At the concluding meeting, a very important and elaborate paper, "On the Impurities of the Air of Towns," was given by Dr. R. Angus Smith, F.R.S., Inspector of Alkali Works. The author, in the course of the paper, referred to the condition of the air of Glasgow and London. His researches on this subject had not been completed; but so far as they went, indicated the greater contamination of Glasgow air.

The number of papers read, and of such high merit, is regarded by the Council as exceedingly encouraging, and as tending to shew that the Section is in a most healthy and promising state.

The Council trust that the members of the parent Society will, in future, avail themselves more largely of their privilege of attending the meetings of the Section.

Mr. David G. Hoey reported on the proceedings of the Section of Sanitary and Social Economy.

SANITARY AND SOCIAL ECONOMY SECTION.

The first paper of the session was read by Mr. George Chapman, on 8th December, 1869, being a critique on Dr. Anderson's Report on the Glasgow Sewage.

Mr. Chapman compared the analyses of the Glasgow sewage, as given in the Report, with those of Messrs. Hoffmann and Witt, which were generally received as the recognized standard of comparison; and he pointed out a great disparity between the two, from which he averred that the Report by Dr. Anderson made out the Glasgow sewage to be entirely different from that of any other place within the United Kingdom. The great discrepancies were especially noticeable in the proportions of ammonia and potash stated as found in the Glasgow sewage.

As regarded the irrigation scheme of Messrs. Bateman and Bazalgette, Mr. Chapman regarded it with extreme disfavour. In no case had sewage irrigation yielded good results to the communities that had adopted it as a means of getting rid of their sewage, with the exception of Rugby and Edinburgh—cases in which there were exceptional circumstances rendering that possible which in the ordinary case was altogether impracticable. The land to be irrigated in the two cases referred to was near at hand, and lay at a low level.

A discussion followed the reading of Mr. Chapman's paper, the general tenor of the remarks being in opposition to the proposed irrigation scheme of Messrs. Bateman and Bazalgette, and to the recommendations contained in Dr. Anderson's Report. The Section, as a whole, was entirely unfavourable to the mode of dealing with human excreta by water-carriage.

The second paper of the session was read by Dr. Gray, on 28th December, the subject being the Sewage question. In his opening remarks, Dr. Gray referred to various expedients that might be adopted to improve the sanitary condition of the city generally. He then proceeded to describe his proposed plan for the disposal of the sewage, which he stated to consist of the forming of large intercepting sewers, running on each side of the Clyde, and receiving in their course the total sewage of the city, including the rainfall, thus interfering as little as possible with the existing sewerage of the city, and not at all in any way with the domestic facilities of the citizens. The water-closet system he regarded as

fixed and immoveable. The North side intercepting sewer to be about nine miles long, and varying in diameter from 4 to 7½ feet—the gradient varying from 4 feet to about 20 inches to the mile. About two-thirds of the sewage of Glasgow to be taken up by the North intercepting sewer, terminating in a receiving tank, from which tank or pond he proposed, by some mechanical means, to lift the sewage a height of about 16 feet, for filtration—the filtrate to pass through and flow into the Clyde nearly pure, the solid filtrant to be retained as a manure for further manipulation. The South side intercepting sewer would be about eight and a half miles long, with diameter from 3 feet to 5¼ feet. The sewage to be utilized in the same manner as on the North side. The gases generated in the sewers to be carried off by tubes raised to a certain height, fitted with argand gas-burners, by which the gases to be burned. The filter, composed of cinders, peat moss, powdered bricks, and gypsum, which is changed once a fortnight or so; but other means might be used.

Dr. Gray calculated that by his process we should be able to manufacture above 120,000 tons of artificial guano; and the nett profit upon each ton he estimated at ten shillings, after paying all expenses.

The general remarks made at the close were in accordance with the formerly-expressed opinions of the Section.

On the 19th January, 1870, the Rev. J. Page Hopps read a paper "On Co-operation," in which he said that existing arrangements, in respect of the employment of labour, had naturally grown out of inevitable conditions and circumstances, but the seneeded re-adjustment, and that every strike or lock-out indicated this. A conflict of interests was producing every species of waste, loss, and distrust. The remedy he proposed was identification of interests as far as possible; and this remedy was to be found in a system of co-operation between capital and labour. The system could be practically illustrated by a reference to several successful enterprises,—notably for reference to the very important colliery at Whitwood, near Normanton, where the Messrs. Briggs had for several years worked their mines on the principle of paying a fixed interest (10 per cent.) to capital, and dividing surplus profits (after making the necessary deductions for wear and tear, &c.) between capital and labour. The result, in every direction, had been remarkable. Savings had been effected, strikes prevented, and orders had been despatched with eager alacrity. The yearly profits had risen from 5 to 14 per cent., and each year's report bore

witness to the fact that, under the new system, more can be got out of an old concern—capital and labour had been alike advantaged.

An interesting discussion followed the reading of the paper.

On 2d February, a paper was read by Mr. William Melvin, "On the Licensing System in Scotland," which gave rise to a warm and animated discussion, that extended over four ordinary fortnightly meetings of the Section. Mr. Melvin, in his opening remarks, stated that he inclined to the opinion that public sentiment would not sustain or sanction legislation in this country, in the direction of the Permissive Bill, for a long time to come. It was likely Government would propose a measure of further restriction for England in the ensuing session. Should legislation be proposed for Scotland, he considered that the following suggestions might be not unworthy of notice, as amendments of the law, viz. :—

(1.) That the maximum number of licenses should be fixed for cities or towns in proportion to the population—say one license for 500 of the population. (2.) That grocers' licenses should be abolished. (3.) That the excise scale of duty should continue to rise, so that, instead of the maximum duty being reached at £50 of rental, as at present, said scale should now be carried up to £200 or even £300 of rental. (4.) That the appeal court be abolished. (5.) That the magistrates of cities and burghs shall alone be empowered to fix the number of licenses to be granted annually —said number never to exceed 1 to 500 of population. (6.) That the ratepayers, by a decided majority in any street, ward, burgh, or parish, shall be empowered to prevent any license being granted or continued in their respective localities against their formally-expressed wish. (7.) That a municipal rate or tax should be imposed on each license, in addition to the excise duty, of at least £30 per annum; and when two or more applicants shall apply for a license, sealed tenders shall be invited, so that the license shall be given to the highest offerer, and said premium, by competition, shall be paid into the said municipal fund. (8.) That said municipal tax or rate on public-houses shall be equally divided between the police-rate, the poor-rates, and fever hospitals of the city or burgh. (9.) That licenses shall only be granted to parties who shall personally superintend said public-houses, and be responsible for good order therein. (10.) That back doors, or concealed entrances to public-houses, shall be illegal and punishable by penalties. (11.) That only one sitting room or public saloon shall be allowed in each public-house, besides the bar or counter. (12.) That every public-house shall be

distant from another licensed house at least 100 yards. (13.) That these public-houses shall close up at 9 P.M. (14.) That drunkards, three times convicted, shall not be knowingly supplied with intoxicating liquors by publicans, under the penalty of loss of license. (15.) That an asylum shall be provided, in which drunkards may be subjected to necessary and legal restraint. (16.) That inspectors shall be appointed for the due enforcement of the law, to be paid out of the municipal rate or tax on public-houses.

The discussion which followed the reading of this paper was both interesting and important, the Council of the Section having invited the attendance of parties known to be interested therein, and representing all varieties of opinion thereon, including magistrates and other gentlemen holding official positions, as well as prominent members and representatives of the spirit trade. This discussion was much too long and varied to render it possible to give even an abstract of it within the limits of the present Report.

On the evening of Wednesday, 30th March, MR. R. M. MACINTYRE, of the Mechanics' Institution, read a paper "On Defects of House Construction."

At the outset of his remarks he stated that in Glasgow the great idea seemed to be spending money in useless decoration, while ventilation was left to accident, and suggested that the authorities should have power to prevent dwelling-houses and workshops being occupied until some means were adopted for their being properly ventilated. The idea that the ordinary fireplace was sure to withdraw the foul air was not only erroneous, but barbarous; and he held that nature pointed to the ceiling as the place by which the vitiated air would readily escape. He condemned the present mode of building in Scotch towns, of piling one house upon another, without leaving sufficient breathing space inside and outside; and also the practice followed in Glasgow, of drawing the water from a cistern which was but rarely, if ever, cleaned out.

The houses which they should build should consist of two apartments, something on the plan of the houses got up in London and its neighbourhood. Supposing that each house cost £100, 5,500 could be built for the sum stated; and at the rate of four or five individuals to each, they could accommodate 28,000 of the population. The rent for these houses—2*s.* to 3*s.* per week—he should fancy, would yield a pretty fair percentage on the money expended. He concluded by saying that the first thing to be done by their authorities was to erect dwelling-houses for workmen at some dis-

tance from the town. These houses might all be joined together; but whatever plan was adopted, a standing rule should be to allow a certain space of ground for every four families or so. Attention should be given to lighting and ventilation, and one, or two at most, water-closets—ventilated towards the outside—should be provided for every four families. Steps should also be taken to induce the railway companies to run cheap trains into the city.

A general discussion followed the reading of the paper.

On Wednesday evening, 20th April, the closing meeting for the session was held, when MR. WILLIAM WALKER read a paper "On Homes for the Reclamation of Young Women," with a glance at the experience of the Home at Lochburn.

Mr. Walker referred at the outset to the change that had come over society, with reference to the treatment of young women who have fallen into open vice. He believed it was the spirit of Christ that was afresh asserting itself as a living power in the hearts of men; and under the influence of that spirit, kindly words were spoken, and sisterly and brotherly hands held out, to help and to raise "the woman that was (or is) a sinner." In nothing was this change more remarkable than in the tone of the highest literature of the day, of which Mr. Walker gave instances from Lecky's *European Morals*, and from the *Contemporary Review*. He then referred to the various refuges that had been opened in London for this unhappy class. Some years ago he had inquired into the history of about twenty of these institutions, and found that only *one* of the twenty belonged to the last century—the Magdalen Hospital, founded in 1758. All the others had been instituted within the last seventy years; most of them, indeed, within the last thirty-five years. The society to which he directed particular attention is called the Rescue Society, and acted upon the plan of having, not one large establishment, but a number of small *Homes*, on the family principle, each having accommodation for from twenty to twenty-five inmates. It had been in operation for about sixteen years, was conducted with great economy in its management, and had been extremely successful in the way of rescuing and reclaiming young women. It had at present twelve Homes, with accommodation in all for about 225 inmates. Mr. Walker referred to a visit he had paid to one of these Homes a few weeks ago, furnishing interesting details illustrative of the spirit in which they are managed, and the success that attends them. Lastly, Mr. Walker gave some account of the origin of the Home at Lochburn, near Maryhill, of which he is a director, with interesting information as to work

Corporation Buildings, March 23, 1870.—*The* PRESIDENT *in the Chair.*

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MR. JOHN M. THOMSON,—"Notes upon the Appearance and Chemical Constitution of Ancient Glass found in Tombs in the Island of Cyprus."

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The Society, on the recommendation of the Council, agreed to grant the sum of £5 to the fund now being collected for the relief of the family of the late Professor Sars of Christiania, Norway. The first vote was taken, and passed unanimously.

MR. PROVAN called attention to the insufficiency of the subscription by members of the Society to meet the expense incurred in removing from the former to the present rooms; and proposed that members who had not contributed for this purpose should be called upon by the collector for their subscriptions,—the call, however, not to be made upon those who have recently joined the Society.

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MR. JAMES THOMSON described the structural characteristics of the different species of Megalichthys, which he illustrated by a suite of specimens, and by sections under the microscope.

Corporation Buildings, April 27, 1870.—*The* PRESIDENT *in the Chair.*

On the assembling of the Society this evening, the PRESIDENT referred to the loss which it had sustained since the last meeting, by the death of Dr. Francis H. Thomson, one of the Vice-Presidents. The President, after making some suitable remarks on Dr. Thomson's character and attainments, and on his long and valuable services to the Society, moved that, out of respect to his memory, the Society do now adjourn for a week, and that the President and Secretary be instructed to prepare a minute expressive of the Society's sense of its loss, and of its sympathy with Dr. Thomson's widow in her bereavement.

Corporation Buildings, May 4, 1870.—*The* PRESIDENT *in the Chair.*

The SECRETARY read the following notice of the death of Dr. Thomson, which he was instructed to insert in the minutes, and communicate a copy of it to Mrs. Thomson:—

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At the next meeting, Mr. E. C. C. Stanford read a paper "On the Action of House Sewage on Lead Pipes," shewing that the pipes are frequently rapidly corroded by the sewage, and leakage of the contents caused thereby.

At the same meeting, Mr. R. R. Tatlock read a paper "On the Estimation of Iodine and Bromine," the method described being based on the fact that bromine replaces iodine, and chlorine replaces both.

At the fourth meeting, Mr. W. R. Hutton read a communication "On Coal-smoke." The author proposed, as a means of diminishing

smoke, to distil the coal to obtain a useful and saleable oil, and then to use the residual coke as fuel.

At the following meeting, a paper, "On Artificial Alizarine," was read by MR. J. W. YOUNG, embodying the results of numerous experiments made by the author on this new and important colouring matter; and on the evening of meeting thereafter, MR. J. CHRISTIE followed with the same subject, treated in a most elaborate and exhaustive manner, and illustrated by numerous dyed specimens of cloth. The proceedings of these two evenings have excited the interest of several of the leading chemists of the country.

At the seventh meeting, MR. A. CAMPBELL, St. Rollox Chemical Works, read two contributions "On Californian Borax and Sicilian Sulphur." MR. JAMES MAHONY then read a note "On the Ooze from the Atlantic Sea-bed, obtained during the Dredging Expedition of H.M.S. *Porcupine;*" which paper was followed by one from MR. STANFORD, "On Shell Sand from the Island of Coll."

MR. CHARLES SMITH, at the succeeding meeting, exhibited several pieces of Chemical and Electrical apparatus, of a kind seldom required in physical researches, explanations being given by Dr. Wallace.

On March 14, MR. W. R. HUTTON occupied the greater part of the evening with a description of Canadian Phosphate of Lime, and other phosphatic substances used in the manufacture of artificial manures. This was followed by a note from MR. MAHONY, "On Plate Sulphate of Potash."

At the next meeting, MR. T. L. PATTERSON described a method of obtaining a continuous blast of air under pressure for blow-pipe and other purposes. The apparatus described was an ingenious adaptation of the principle of the Sprengel air-pump.

At the concluding meeting, a very important and elaborate paper, "On the Impurities of the Air of Towns," was given by DR. R. ANGUS SMITH, F.R.S., Inspector of Alkali Works. The author, in the course of the paper, referred to the condition of the air of Glasgow and London. His researches on this subject had not been completed; but so far as they went, indicated the greater contamination of Glasgow air.

The number of papers read, and of such high merit, is regarded by the Council as exceedingly encouraging, and as tending to shew that the Section is in a most healthy and promising state.

The Council trust that the members of the parent Society will, in future, avail themselves more largely of their privilege of attending the meetings of the Section.

Mr. David G. Hoey reported on the proceedings of the Section of Sanitary and Social Economy.

SANITARY AND SOCIAL ECONOMY SECTION.

The first paper of the session was read by Mr. George Chapman, on 8th December, 1869, being a critique on Dr. Anderson's Report on the Glasgow Sewage.

Mr. Chapman compared the analyses of the Glasgow sewage, as given in the Report, with those of Messrs. Hoffmann and Witt, which were generally received as the recognized standard of comparison; and he pointed out a great disparity between the two, from which he averred that the Report by Dr. Anderson made out the Glasgow sewage to be entirely different from that of any other place within the United Kingdom. The great discrepancies were especially noticeable in the proportions of ammonia and potash stated as found in the Glasgow sewage.

As regarded the irrigation scheme of Messrs. Bateman and Bazalgette, Mr. Chapman regarded it with extreme disfavour. In no case had sewage irrigation yielded good results to the communities that had adopted it as a means of getting rid of their sewage, with the exception of Rugby and Edinburgh—cases in which there were exceptional circumstances rendering that possible which in the ordinary case was altogether impracticable. The land to be irrigated in the two cases referred to was near at hand, and lay at a low level.

A discussion followed the reading of Mr. Chapman's paper, the general tenor of the remarks being in opposition to the proposed irrigation scheme of Messrs. Bateman and Bazalgette, and to the recommendations contained in Dr. Anderson's Report. The Section, as a whole, was entirely unfavourable to the mode of dealing with human excreta by water-carriage.

The second paper of the session was read by Dr. Gray, on 28th December, the subject being the Sewage question. In his opening remarks, Dr. Gray referred to various expedients that might be adopted to improve the sanitary condition of the city generally. He then proceeded to describe his proposed plan for the disposal of the sewage, which he stated to consist of the forming of large intercepting sewers, running on each side of the Clyde, and receiving in their course the total sewage of the city, including the rainfall, thus interfering as little as possible with the existing sewerage of the city, and not at all in any way with the domestic facilities of the citizens. The water-closet system he regarded as

fixed and immoveable. The North side intercepting sewer to be about nine miles long, and varying in diameter from 4 to 7½ feet—the gradient varying from 4 feet to about 20 inches to the mile. About two-thirds of the sewage of Glasgow to be taken up by the North intercepting sewer, terminating in a receiving tank, from which tank or pond he proposed, by some mechanical means, to lift the sewage a height of about 16 feet, for filtration—the filtrate to pass through and flow into the Clyde nearly pure, the solid filtrant to be retained as a manure for further manipulation. The South side intercepting sewer would be about eight and a half miles long, with diameter from 3 feet to 5½ feet. The sewage to be utilized in the same manner as on the North side. The gases generated in the sewers to be carried off by tubes raised to a certain height, fitted with argand gas-burners, by which the gases to be burned. The filter, composed of cinders, peat moss, powdered bricks, and gypsum, which is changed once a fortnight or so; but other means might be used.

Dr. Gray calculated that by his process we should be able to manufacture above 120,000 tons of artificial guano; and the nett profit upon each ton he estimated at ten shillings, after paying all expenses.

The general remarks made at the close were in accordance with the formerly-expressed opinions of the Section.

On the 19th January, 1870, the Rev. J. Page Hopps read a paper "On Co-operation," in which he said that existing arrangements, in respect of the employment of labour, had naturally grown out of inevitable conditions and circumstances, but the seneeded re-adjustment, and that every strike or lock-out indicated this. A conflict of interests was producing every species of waste, loss, and distrust. The remedy he proposed was identification of interests as far as possible; and this remedy was to be found in a system of co-operation between capital and labour. The system could be practically illustrated by a reference to several successful enterprises,—notably for reference to the very important colliery at Whitwood, near Normanton, where the Messrs. Briggs had for several years worked their mines on the principle of paying a fixed interest (10 per cent.) to capital, and dividing surplus profits (after making the necessary deductions for wear and tear, &c.) between capital and labour. The result, in every direction, had been remarkable. Savings had been effected, strikes prevented, and orders had been despatched with eager alacrity. The yearly profits had risen from 5 to 14 per cent., and each year's report bore

witness to the fact that, under the new system, more can be got out of an old concern—capital and labour had been alike advantaged.

An interesting discussion followed the reading of the paper.

On 2d February, a paper was read by MR. WILLIAM MELVIN, "On the Licensing System in Scotland," which gave rise to a warm and animated discussion, that extended over four ordinary fortnightly meetings of the Section. Mr. Melvin, in his opening remarks, stated that he inclined to the opinion that public sentiment would not sustain or sanction legislation in this country, in the direction of the Permissive Bill, for a long time to come. It was likely Government would propose a measure of further restriction for England in the ensuing session. Should legislation be proposed for Scotland, he considered that the following suggestions might be not unworthy of notice, as amendments of the law, viz.:—

(1.) That the maximum number of licenses should be fixed for cities or towns in proportion to the population—say one license for 500 of the population. (2.) That grocers' licenses should be abolished. (3.) That the excise scale of duty should continue to rise, so that, instead of the maximum duty being reached at £50 of rental, as at present, said scale should now be carried up to £200 or even £300 of rental. (4.) That the appeal court be abolished. (5.) That the magistrates of cities and burghs shall alone be empowered to fix the number of licenses to be granted annually —said number never to exceed 1 to 500 of population. (6.) That the ratepayers, by a decided majority in any street, ward, burgh, or parish, shall be empowered to prevent any license being granted or continued in their respective localities against their formally-expressed wish. (7.) That a municipal rate or tax should be imposed on each license, in addition to the excise duty, of at least £30 per annum; and when two or more applicants shall apply for a license, sealed tenders shall be invited, so that the license shall be given to the highest offerer, and said premium, by competition, shall be paid into the said municipal fund. (8.) That said municipal tax or rate on public-houses shall be equally divided between the police-rate, the poor-rates, and fever hospitals of the city or burgh. (9.) That licenses shall only be granted to parties who shall personally superintend said public-houses, and be responsible for good order therein. (10.) That back doors, or concealed entrances to public-houses, shall be illegal and punishable by penalties. (11.) That only one sitting room or public saloon shall be allowed in each public-house, besides the bar or counter. (12.) That every public-house shall be

distant from another licensed house at least 100 yards. (13.) That these public-houses shall close up at 9 P.M. (14.) That drunkards, three times convicted, shall not be knowingly supplied with intoxicating liquors by publicans, under the penalty of loss of license. (15.) That an asylum shall be provided, in which drunkards may be subjected to necessary and legal restraint. (16.) That inspectors shall be appointed for the due enforcement of the law, to be paid out of the municipal rate or tax on public-houses.

The discussion which followed the reading of this paper was both interesting and important, the Council of the Section having invited the attendance of parties known to be interested therein, and representing all varieties of opinion thereon, including magistrates and other gentlemen holding official positions, as well as prominent members and representatives of the spirit trade. This discussion was much too long and varied to render it possible to give even an abstract of it within the limits of the present Report.

On the evening of Wednesday, 30th March, MR. R. M. MACINTYRE, of the Mechanics' Institution, read a paper "On Defects of House Construction."

At the outset of his remarks he stated that in Glasgow the great idea seemed to be spending money in useless decoration, while ventilation was left to accident, and suggested that the authorities should have power to prevent dwelling-houses and workshops being occupied until some means were adopted for their being properly ventilated. The idea that the ordinary fireplace was sure to withdraw the foul air was not only erroneous, but barbarous; and he held that nature pointed to the ceiling as the place by which the vitiated air would readily escape. He condemned the present mode of building in Scotch towns, of piling one house upon another, without leaving sufficient breathing space inside and outside; and also the practice followed in Glasgow, of drawing the water from a cistern which was but rarely, if ever, cleaned out.

The houses which they should build should consist of two apartments, something on the plan of the houses got up in London and its neighbourhood. Supposing that each house cost £100, 5,500 could be built for the sum stated; and at the rate of four or five individuals to each, they could accommodate 28,000 of the population. The rent for these houses—2*s.* to 3*s.* per week—he should fancy, would yield a pretty fair percentage on the money expended. He concluded by saying that the first thing to be done by their authorities was to erect dwelling-houses for workmen at some dis-

tance from the town. These houses might all be joined together; but whatever plan was adopted, a standing rule should be to allow a certain space of ground for every four families or so. Attention should be given to lighting and ventilation, and one, or two at most, water-closets—ventilated towards the outside—should be provided for every four families. Steps should also be taken to induce the railway companies to run cheap trains into the city.

A general discussion followed the reading of the paper.

On Wednesday evening, 20th April, the closing meeting for the session was held, when Mr. William Walker read a paper "On Homes for the Reclamation of Young Women," with a glance at the experience of the Home at Lochburn.

Mr. Walker referred at the outset to the change that had come over society, with reference to the treatment of young women who have fallen into open vice. He believed it was the spirit of Christ that was afresh asserting itself as a living power in the hearts of men; and under the influence of that spirit, kindly words were spoken, and sisterly and brotherly hands held out, to help and to raise "the woman that was (or is) a sinner." In nothing was this change more remarkable than in the tone of the highest literature of the day, of which Mr. Walker gave instances from Lecky's *European Morals*, and from the *Contemporary Review*. He then referred to the various refuges that had been opened in London for this unhappy class. Some years ago he had inquired into the history of about twenty of these institutions, and found that only *one* of the twenty belonged to the last century—the Magdalen Hospital, founded in 1758. All the others had been instituted within the last seventy years; most of them, indeed, within the last thirty-five years. The society to which he directed particular attention is called the Rescue Society, and acted upon the plan of having, not one large establishment, but a number of small *Homes*, on the family principle, each having accommodation for from twenty to twenty-five inmates. It had been in operation for about sixteen years, was conducted with great economy in its management, and had been extremely successful in the way of rescuing and reclaiming young women. It had at present twelve Homes, with accommodation in all for about 225 inmates. Mr. Walker referred to a visit he had paid to one of these Homes a few weeks ago, furnishing interesting details illustrative of the spirit in which they are managed, and the success that attends them. Lastly, Mr. Walker gave some account of the origin of the Home at Lochburn, near Maryhill, of which he is a director, with interesting information as to work

carried on there. He shewed that as an industrial institution it had been a great success; but expressed his opinion that in our city there was still room for an effort of the kind carried on by the Rescue Society in London. The proportion of unsatisfactory cases in London—that is, of young women who leave the homes without getting any good—was smaller than shewn in Glasgow, while the proportion apparently permanently reclaimed was larger. Mr. Walker thought that, without at all interfering with the work at Lochburn, there was room in Glasgow for a well-devised effort in the way of small Homes.

In the general remarks which followed, much interest was expressed in the subject of the paper, and in the felicitous manner in which it had been brought before the Section by Mr. Walker.

The President then declared the session closed.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SIXTY-NINTH SESSION.

I.—*Opening Address by* JAMES BRYCE, M.A., LL.D., F.G.S., *the* PRESIDENT.

November 2, 1870.

HAVING made some introductory observations in regard to the present position of the Society, and reviewed briefly the papers read during the past session, the PRESIDENT went on to give an account of the chief incidents in the lives of two deceased Members long connected with the Society, and prominent in the community.

OBITUARY NOTICES.

DR. FRANCIS H. THOMSON.—It is now my sad duty to refer to the loss which the Society sustained at the close of last session by the death of its Senior Vice-President. In the full vigour of mature life, amid circumstances which gave almost a tragical character to the event, Dr. Francis H. Thomson was suddenly removed from the midst of us. He had been during the whole winter taking an active part in the business of the Society, never absent from its meetings, and working vigorously in its interests. Married on the 25th February to an amiable and accomplished lady, to whom he had been long attached, he had arranged to remove to a larger residence, to have an assistant who should relieve him of part of his heavy professional work, that he might at length enjoy more leisure and the better fulfil the new duties devolving upon him; and then went abroad for a short holiday. But "our times" are not in our own hands; "propose" as we may, we cannot "dispose." From this tour he never returned. He died in London on the 21st of April.

Dr. Thomson's ancestors were lairds of Newton of Colessie in Fife. His grandfather was minister of Dailly, in Ayrshire, and was twice married—first, to the daughter of the Hon. Sir Alexander Hope of Carse, and afterwards to a daughter of Francis Hay, in Lochside, parish of Dundonald. Of this second marriage there came four daughters and four sons. One of the former married Mr. James Pillans, Professor of Humanity in the University of Edinburgh; two of the latter became distinguished members of the literary circles of Edinburgh at the beginning of this century, and have left their mark upon their time; a third was the father of the subject of this notice, Francis Hay Thomson, born at Giffard Bank, East Lothian, on the 2d of February, 1814. His father, Adam Thomson, was an accountant in Edinburgh; one of his uncles above referred to, Thomas Thomson, was an advocate in Edinburgh, principal clerk to the Court of Session, and keeper of the Records, author of many historical and antiquarian works prepared for the Bannatyne Club, or by order of the Royal Commissioners of Records,—an intimate friend of almost all the celebrated men of the northern metropolis, on whose fame her literary reputation now mainly rests. An interesting memoir of his life, with copious extracts from his correspondence with these eminent men, was drawn up by Mr. Cosmo Innes, and printed for private circulation in 1854, two years after his death. The other uncle, to whom reference has been made above, was the Rev. John Thomson, minister of the parish of Duddingston, near Edinburgh, who has acquired a well-deserved reputation as a landscape painter, and has been called, from his peculiar style, the Scottish Claude. The character, tastes, teachings, the whole surroundings of such men, the tone of the society in which they mingled, had no doubt a powerful influence upon a young man of an ardent, earnest character, and were the means of establishing those mental tendencies which determined his pursuits, outside of his profession, and formed the main pleasures of his leisure time through his whole life. A mechanical turn of mind, and nicety of hand, which were natural to him, and a pleasure in chemical manipulation afterwards acquired, led him to adopt, at an early age, that branch of the medical profession which promised to afford him most leisure for indulging those tastes to which allusion has been made. To this choice he steadfastly adhered; and he rose by his talent and industry to the first eminence in the profession.

Dr. Thomson was educated at the High School of Edinburgh, and afterwards at the University, where, in the classes of his

relative, Professor Pillans, he was a distinguished student. He took at this time only a partial course of medicine at the University, and was soon after articled as a pupil to Mr. Hutchins, the well-known surgeon-dentist in Edinburgh. On the expiry of his term he took an assistantship to a practitioner in Yorkshire, but did not long remain there. He returned to Edinburgh, and began to practise on his own account. Here he remained for five years, and now took an opportunity of completing his medical course. His degree of M.D., however, was taken from the university of Jena. During his sojourn in Edinburgh, the position of his family and near relatives gave him an entrance into the literary circles, which were at that time an ornament to the Scottish metropolis; and he no doubt derived great benefit in the way of intellectual activity and polish from association with such society.

In 1843, being then in his twenty-ninth year, an opening having occurred in Glasgow, he removed to this city, and entered on that successful career of professional life which gave him in later years a very large income. No one could deserve better such a reward, and few could have used it better. He was, in his own life, simple and inexpensive; towards others, open-hearted and generous; and many a family, left helpless by sudden bereavement, acknowledged him as a generous benefactor who relieved present distress, and led them on new paths of self-dependent efforts, whereon to retrieve their fortunes.—In the winter of 1844 he joined our Society, and continued from that time to be a zealous working member, ever devoted to its welfare. His first public services were given in 1846, at the time of the exhibition got up by the Society, which proved so great a success. He took an active part in all the arrangements, and the department of the fine arts was entirely under his management. In succeeding years he filled various offices in the Society, and became, four years ago, the first President of the Society not a professor in the University. With what credit to himself and profit to us he filled that office, is fresh in the recollection of all.

Dr. Thomson had an early fondness for chemistry, which he retained in his maturer years; but he made original researches in one department only—that of metallurgy. In the history of this art, especially as regards copper, he was well versed, keeping pace with the improvements of modern times. In 1849 he instituted a set of experiments to test what he considered an improved method of reducing the ore. Trap-rock had occurred to him as a fusible silicate, containing the necessary elements of reduction; and with

it he made the experiments on such a large scale as to remove them from the category of mere laboratory trials. These experiments he considered quite successful; the material was as cheap as could be desired, and in quantity unlimited. He acknowledged the objection against its use on account of bulk; but he regarded this as over-ruled by the saving of fuel, from the shortness of the process. He now proceeded to take out a patent for the process, dated the 14th September in that year. But although the principle was perfectly correct, and practically the metal was obtained quite pure, the patent was not successful in a commercial point of view. For this, various reasons may be assigned. Copper-smelting has become centralized in a district where there is no whinstone, and the Clyde district, where it abounds, has never taken with energy or success either to copper or steel works. Such failure is indeed very common with patentees; the process may be correct enough in principle, but want of experience in practical details prevents them from knowing the commercial bearings of the invention; and this is really the great test of success.

In 1857 he took out another patent for improvements in the manufacture of iron. The idea, in this case, was to introduce carbon into the blast-furnace, so as to counteract the effect of the too rapid combustion or decarbonization of the iron by the oxygen contained in the stream of air thrown into the furnace; and it was carried into effect by introducing, by a second pipe, a stream of a carbonaceous gas. This patent, however, shared the fate of the other, the idea being carried out in some other manner, found equally efficient and more economical.

Subsequently to these attempts, Dr. Thomson was for some time engaged in experiments on nickel, with a view to another patent; but the idea was abandoned.—It is pleasant to know that the losses he sustained by these repeated failures were not very considerable, and his mind was too well balanced to allow such things to trouble him.

Dr. Thomson's active intellect, his inventive powers, and artistic tastes went out in other directions, which were to him productive of more pleasure and enjoyment. He was endowed by nature with capabilities for excelling in art; he had the gifts of form and colour; and one can see how early home-teachings and the example and teachings of his uncles would improve and confirm such gifts, the one in the department of painting and sculpture, the other in regard to objects of art as illustrating history and antiquities. To the cultivation of these his leisure hours and holidays were chiefly

given. He was early left a widower, with one child—a daughter—and family duties made few demands upon his time. His merit as a painter was very considerable, and he would certainly have reached high excellence and fame had he given himself up to art. Some of his pictures, painted from his own sketches of natural scenery, possessed so much merit as to be deemed worthy of a place in the Edinburgh Annual Exhibition. As a sculptor also he had great merit; some busts executed by him shew a power not only of expressing likeness, but of imparting those idealizing poetic adjuncts which give so great a charm to works of this class. In regard to all works of art he was an accomplished critic. His taste and judgment found ample exercise in the formation of a large and valuable collection of gems, cameos, and other objects of *vertu* illustrating the history and progress of art, as well as a few sculptures. This collection adorned his home, and was well known beyond the limits of his own country.

Dr. Thomson was too much occupied by his large professional practice to find time for writing many papers. He served this Society in another way, and was ever ready to undertake more than his share of work on behalf of the Society. His extraordinary exertions in connection with our removal to this building will be fresh in your recollection. It was mainly through his persevering efforts, directed by his strong will and energy of character, and his experience in the management of affairs, that the delicate negotiations were brought to a successful issue, the fruits of which we shall enjoy so long as we stand in our present relations with the Corporation of the city. The amount of anxious thought, and the sacrifice of time entailed by these negotiations, are known to those only who were associated with him in the Council of the Society. With them his intercourse was of the most friendly confiding nature. So pleasant and genial was he, and though of great energy and force of will, so ready to yield his opinion, and fall in with the general sentiment on any matter in debate, that his presence was ever welcome; and his occasional absence was felt as a drawback on our pleasure and enjoyment for that evening.

The first paper contributed by him to the Society was on a professional subject, and appeared in our Journal in 1846, vol. ii., p. 131. His next was published in 1860, vol. iv., p. 325. It was on the subject of copper-smelting, and contained references to his patent. His next paper was on the application of certain salts to the rendering of light fabrics less inflammable (Journal, vol. v., p. 92). His three addresses, as President, are the only

other papers he contributed. His first described the industries of Glasgow; his second gave an account of the jute works of Dundee; and his third contained an able criticism on the great scheme of Bateman and Bazalgette for removing the Glasgow sewage. These will be found in vols. vi. and vii. of our Journal. These papers are full of interesting information, delivered in a style rapid, picturesque, and perfectly perspicuous. They will amply repay perusal. He often spoke of some curious observations he had made, while experimenting for his patent, on the melting of stony masses, and the forms and structures they had assumed in cooling, according to the rate at which the temperature was reduced. From what I could gather, they seemed to illustrate and confirm the celebrated experiments of Gregory Watt, made at the Soho foundry in 1804, in regard to the resumption of the solid form by melted trap. I hope yet to be able to lay before the Society some account of these observations and experiments.

DR. FREDERICK PENNY.—Scarcely was the record completed, in which at this time last year I detailed to you the scientific labours of a great chemist, once a prominent member of this Society, when another member, eminent in the same walk, and long an occupant of the same chair, passed suddenly away from the midst of us. You will understand me to allude to the death of Dr. Frederick Penny, Professor of Chemistry in the Andersonian University, which occurred at his own house in this city, on the 22d of November last, after a short illness.

Frederick Penny was born in London, 10th April, 1816. He was the third son of Charles Penny, long established as a wholesale stationer in Cheapside, a man of good substance and highly respected. When Frederick was but two years of age, he received such cruel treatment at the hands of his nurse that the spine was permanently injured, and the deformity, which so curtailed his means of enjoyment in life, gradually arose. Notwithstanding this defect, he had constant good health, was an active lad in all games and sports, an untiring climber and pedestrian. One cannot but admire and respect the strong and earnest spirit which bore up under, and triumphed over, the natural disadvantages which this defect entailed, and which moved him to maintain to the last the vigorous pursuit of work.

Frederick Penny was educated partly at the Sherborne School, in Dorsetshire, and later at Dr. Lord's Academy, at Tooting. He often bore away prizes in the class competitions, and showed great

aptness in mathematics. He early acquired a fondness for chemistry, and, like most young chemists, experimented in a garret at home with improvised apparatus. Having shewn this bent towards the study, and his two older brothers being destined to carry on their father's business, Frederick, at the age of seventeen, was, in 1833, introduced by Dr. Roberts, the family physician, to Mr. Hennell, Chemist to the Apothecaries' Company, and the result was that he was apprenticed to him for five years, at £100 per annum, one apprentice only being taken into the establishment. In 1836 and 1837 he attended the lecture courses of Brande, Faraday, and Lindley, thus widely enlarging the range of his acquirements in science.

Soon after this he entered on the enquiry, which gave rise to his first paper, and I am inclined to think the most able and chemically important which he ever wrote. It was deemed of such interest as to find a place in the *Transactions of the Royal Society of London*, having been previously read at one of their meetings. Not being a Fellow of the Society himself, and to the last he did not join that Society, the paper was communicated by Mr. Hennell, on January 24, 1839. It was printed in the volume for that year. It is entitled, "On the Application of the Conversion of Chlorates and Nitrates into Chlorides, and of Chlorides into Nitrates, to the Determination of several Equivalent Numbers." The result of a long experimental enquiry on the constitution of crude saltpetre, and on certain nitrates and chlorates, was the determination of the atomic weights of chlorine, nitrogen, potassium, sodium, and silver, the calculations being made on the supposition that the atomic weight of oxygen was eight times that of hydrogen, about which chemists were agreed. It was proved that the estimates in general use among British chemists were not representatives of chemical truth; and Dr. Penny's researches went, so far as the enquiry extended, to disprove the theory of Prout, advocated so elaborately by Thomas Thomson, that all atomic weights were multiples of that of hydrogen. This theory, by its simplicity and beauty, and the array of examples set forth in support of it, had commended itself to, and been adopted by, most British chemists. Edward Turner was the first to assail it, and to publish experiments in disproof of it. The equivalents determined by Penny agree much more closely with those of Turner than with Thomson's, and thus go to support Turner's views. In regard to this first effort of Penny, I may say, without exaggeration, that it compares most favourably, in the conduct of the researches, in the mode of dealing with the complicated questions, as well as in its

style and manner, with the productions of our most eminent chemists. It established a reputation for him at once, attracted to him the attention of Graham, who had now been two years in the chemical chair of University College. He requested Mr. Hennell to introduce him to Mr. Penny. Soon after, he invited him to his house, and advised him to apply for the chair in the Andersonian University, vacated two years before by himself, and just vacated by Dr. Gregory, then transferred to Aberdeen, and who afterwards defeated Penny in the contest for the chair of Hope, in Edinburgh. Penny took this advice, got a few testimonials—among them one from Graham,—£50 from his father, "to go and see the Scotch Highlands at any rate," came to Glasgow, saw the Directors, left copies of his testimonials, and went for his three weeks' tour. On his return he found he had got the appointment.

But this did not mean much more than that he had their authority to lecture within the walls of the Andersonian Institution. The chair had never been lucrative,—so poor indeed under Gregory, that the Directors had to forego their claim for rent, his pupils not having exceeded fifty or sixty. Dr. Penny's prospects were thus rather gloomy; but he was young, full of hope, of indomitable energy, and determined to give prominence and usefulness to the chair of Ure, Clark, and Graham. He had to begin by supplying apparatus and all the requisites for a laboratory, and besides to meet the supply of coal and gas, and pay rent and taxes, as best he could. But he rose successful over all these disadvantages. At the end of his first year he had eighty-seven students; at the beginning of his thirtieth session, shortly before his death, the number of students was eight hundred; and his practical class had been, for many years before, larger than any in the United Kingdom, except the College of Chemistry in London.

From the time of his appointment in 1839 up till the time of his marriage with Miss Perry of this city in 1851, Dr. Penny generally spent his holidays with or near his father. The attachment of father and son was unusually strong. Reserved and reticent by natural temperament towards his other children, Mr. Penny was unreserved and demonstrative in a high degree towards his son Frederick. For years they exchanged letters every day, and their mutual affectionate attachment partook more of that of two brothers or devoted friends, than of persons standing in the relationship they occupied. During one of these visits, in 1843, Dr. Penny had been to see his old friend and master Mr. Hennell. He was then experimenting on an explosive mixture; and Dr. Penny made an appointment with

him to be at the laboratory at ten o'clock on the following morning to witness the result of the experiment. On that morning, in slicing a loaf of bread at breakfast, by one of those singular accidents which often shew to individuals a "gracious purpose" towards them, which too seldom influences the whole after-life as it ought to do, he gave a bad cut to one of his fingers. This caused such a delay that, when he was ready to go out, the hour of appointment with Mr. Hennell was considerably past; and he remarked to one of his sisters, that there was no use in going now, as the experiment would be over. The experiment was indeed over. In making it by himself, without assistant or witness, Mr. Hennell was killed on the spot, his body being literally blown to pieces, and the whole laboratory greatly injured.

Soon after this Dr. Penny was offered the situation which had been filled by Mr. Hennell; but the income not being very tempting, and feeling he had now secured a good position in Glasgow, he declined the proffered office. Dr. Penny indeed had all those qualities which deserve and usually ensure success. He had a high estimate of his science, an ardent love for the study, and he was enthusiastic in its pursuit. Enthusiasm is infectious, and the surest way to interest and excite others is to be enthusiastic and interested oneself. But perhaps the most distinguishing feature of his teaching was his clearness and method. He had got hold of the important principle that to establish ideas firmly in the mind, they ought to be presented singly—one understood and rooted before another is presented—and that discursive lecturing on science, however pleasant to listen to, as coming from a full and earnest mind, is not profitable to the student. Of everything that he undertook to do, or to speak of, he formed the most clear and accurate conceptions; and he was able to set these before the mind of another with the most admirable clearness and precision. This mental habit, united to his great natural sagacity and mathematical attainments, made him an admirable analyst, and a legal witness whom it was impossible to dislodge from a position taken up, or to bring to contradict himself by any amount of cross-examination. So early was his reputation in these walks of chemistry established, that for the last twenty-five years he had been retained by the Crown prosecutor in Scotland in all criminal cases where chemical knowledge was requisite, or chemical questions were involved. But his profound chemical knowledge and his great and penetrating sagacity were often in request in other than criminal cases. Some of these, in which the issues involved about a

million sterling, hinged almost wholly on his evidence. But I can only thus allude, in passing, to topics of this kind, nor is it necessary, as the transactions are fresh in your minds. To one other passage only of his life will I allude, and then briefly mention his remaining papers.

His reputation as a chemist, and the motives under which he acted, were at one time assailed in connection with the water supply of the city. Both charges, I believe, were wholly without foundation. There was much excitement at the time in the public mind, and personal feelings ran high; but when time had allayed these, and a calmer judgment was exercised, his opinion was found not to be that of a partizan; and though some hard speeches were uttered, no one could, in the long run, seriously believe that a man of his antecedents, position, and ample means, would, for any consideration, endanger his scientific reputation, or be swayed by such motives as in the heat of angry feeling were ascribed to him.

Dr. Penny had his degree of Doctor in Philosophy from the University of Giessen. He joined the Royal Society of Edinburgh in 1856. He was a member also of the Chemical Society of London. The last work on which he was engaged, was the charge of the arrangements for preserving the purity of the river Esk, which passes through Dalkeith, and had been polluted by refuse from paper works. Having been employed in a lawsuit regarding it when a compromise was effected, and time allowed to the paper makers, he was assumed as their adviser in regard to the disposal of offensive matter, and the preservation of the purity of the stream. His chief assistant resided there, and was in constant employment on this guardianship of the river. Since Dr. Penny's death he has been given the entire direction and control of all the operations for the preservation of the purity of the water, and the safe disposal of any polluting matters.

At the close of his paper to the Royal Society, of which I have already spoken, Dr. Penny alludes to other kindred researches on which he had entered, and of which he hoped, at a future time, to give an account to the Society. This hope, however, was not realized, for want of leisure. His professional engagements here, his charge of a great laboratory, the demand upon his time for commercial analyses, for reports on matters in dispute at law, and in connection with several public questions, withdrew him from the line of sustained original research, in which there was every hope that he would have shone. His remaining papers are thus not in any kind

of series or dependence, yet are they indicative of great activity, and profound knowledge of the whole range of the science.

The year after his appointment, the British Association met for the first time in Glasgow; and to the Chemical Section he then contributed two papers, the second and third of which he was author; one "On the Action of Nitric Acid on certain Soda Salts," and the other "On a New Salt obtained from Iodine and Caustic Soda." From the researches in the former of these he hoped to have obtained the more accurate atomic weights of some of the elements, in the same manner as in his paper of the year before; but he found the action not delicate enough for the purpose. The results, however, which he obtained were new, and interesting enough to be worth the attention of the Section. He shewed that the action of nitric acid on the chlorates, iodates, and bromates of soda and potassa, afforded a ready mode of distinguishing these salts. The other paper brought out a curious property in connection with the crystallization of the salt obtained from iodine and caustic soda (*Report of Glas. Meet., Brit. Assoc.*, 1840, pp. 79, 80).

4. In a paper which appeared in vol. i. of the Journal of our Society, published 1843, p. 104, Dr. Penny describes the structure and composition of a specimen of Asbestos, found in a blast-furnace at Monkland Ironworks.

5. His next paper is "On a New Method for the Determination of Iron in Clay-band and Black-band Ironstone." He recommends in this paper the employment of the chromate and bichromate of potash for determination of the iron in the common ores; the same process would answer for the analysis of other ores, and for examining alum and copperas liquor (*Report of Edin. Meet., Brit. Assoc.*, 1850, p. 58).

6. The only other paper of Dr. Penny's laid before our Society was drawn up in conjunction with Mr. William Wallace, and read, January 7, 1852, but published in the *Philosophical Magazine*, Nov., 1852, "On the Chloride of Arsenic, partly in reference to the equivalent number for arsenic, and partly on its use in separating arsenic from animal and vegetable matters, and its use in medico-legal enquiries."

7. "On the Valuation of Indigo," read to the Chemical Society of London, Nov., 1852, in which the several methods employed for estimating the comparative value of commercial indigo are examined, and the bichromate of potash is recommended as a trustworthy agent of valuation (*Jour. of Chem. Soc.*, 1852).

8. "On the Valuation and Composition of Protochloride of Tin,"

of which a large quantity is yearly made in Glasgow (*Jour. Chem. Soc.*, vol. iv., 1852, p. 239).

9. "On the Estimation of Iodine," another paper having reference to a large industry in Glasgow, and in which bichromate of potash is recommended again as the agent (*Rep. Belfast Meet., Brit. Assoc.*, 1852, p. 37).

10. Another paper or "note" on the Protochloride of Tin (*Jour. Chem. Soc.*, vol. vii., p. 50, 1854).

11. "On a simple Volumetric Process for the Valuation of Cochineal" (*Rep. Glas. Meet., Brit. Assoc.*, 1855, p. 68). The process is based on a property of the red prussiate of potash in presence of a free alkali.

12. "On the Manufacture of Iodine and other Products from Kelp" (*Rep. Glas. Meet., Brit. Assoc.*, 1855, p. 69).

13. "On the Composition and Phosphorescence of Plate-sulphate of Potash" (*Rep. Glas. Meet., Brit. Assoc.*, 1855, p. 69). This salt is made almost wholly in Glasgow, and its history has great scientific interest.

These are all the scientific papers I know of as having appeared in the Journals, and it will be observed of all of them, except the short notice of Asbestos, that they relate to the composition of commercial products which came before Dr. Penny professionally for examination. They contain many excellent analyses and useful hints to chemists for the accurate examination of such products. But his reputation as a man of science, who really advanced chemical theory, must rest mainly on his first paper; his local celebrity, on his admirable sagacity and skilful methods in the detection of poisons.

He was besides the author of several reports: one addressed to the Gorbals Gravitation Water Company, entitled, "Chemical Report on the Water of Loch Katrine," *Glasgow, Macnab, printer*, 1854, pp. 69; another, addressed to the Loch Katrine Water Commissioners, entitled, "Report on the Experimental Operations at Loch Katrine," *London, John Haeffele, printer*, 31 *Bush Lane, Cannon Street*, 1855. At the close of this report he sums up the conclusions drawn from the enquiries detailed in both reports in an emphatic condemnation of the introduction of Loch Katrine water through lead pipes; and urges the employment of a simple remedy to prevent such action on pipes and cisterns. This is the introduction of a hard and less pure water to mix with the soft Loch Katrine water, by streams and springs in the course of the great conduit, so as to introduce earthy salts into it, and thus to modify

the dangerous properties of the water. The fact is, that from 1 to $1\frac{1}{2}$ grains per gallon of earthy salts are found in the water when it reaches Glasgow, more than is found in it when taken from the Loch; and this difference is quite sufficient to prevent its action on lead.

Dr. Penny was also the author, in conjunction with Dr. James Adams, of two pamphlets: one "On the Detection of Aconite by its Physiological Action," in connection with a celebrated poisoning case, *Glasgow, W. M'Kenzie*, 1865; and another "On the Composition and Dietetic Properties of Hungarian Wines," extracted from a work by various writers, "On Pure or Natural Wines," but without date or printer's name. There are besides several printed reports of his evidence in certain lawsuits for the use of judges and juries, which display an extraordinary sagacity and grasp of mind, and a profound knowledge of chemistry in all its varied applications.

PROGRESS OF SCIENCE.

The mental activity of the present time is in many ways remarkable. Research and discovery are not, as formerly, confined to a few in the learned or professional classes. Many men of slight preparatory training have started into sudden activity, and contributed not a little to the advancement of science. Much is no doubt put forward that is ill-digested; speculative hypotheses are built up on a few facts or narrow inductions, and pass with the unreflecting for true theories. Though intended by their authors as mere hypotheses, centres around which facts may be made to cluster having all one probable suggested bearing; yet are the results, which could only be reached by a long patient generalization, hastily anticipated, and a crude hypothesis accepted as scientific truth. The recent progress of scientific enquiry illustrates this in many departments. The abuse is, however, one of a subjective kind, and forms no argument against the culture of science. Let such hypotheses be set forth by all means, if only with becoming modesty and duly guarded: further research, more careful enquiry, will sift out the good; the bad will be cast away. At all hazards, on all subjects, let enquiry be encouraged and promoted. To discourage it as dangerous is to be mistrustful, afraid of truth, and is worse than useless: for, counsel as you may, men will enquire, search, and speculate; and if they fail in their logic and in their philosophy, led away by "science falsely so called,"

entangled in the mazes of "a vain and deceitful philosophy," time will somehow unfold the error, and the grain of truth will remain. Truth anywhere found, in nature, in science, in revelation, will be self-consistent, uncontradictory, and must be good and useful. Encourage, then, its discovery; but warn the enquirer that it lies deep down and is not easily reached—that he will not attain to it by a superficial search over many fields, and had best limit his enquiry to a narrow area. Counsel him to imitate the simplicity and modest caution of such men as Dalton, Faraday, and Graham, to remember his own feeble smallness in presence of the vast works, movements, and mysteries of nature—his own days of life as an handbreadth beside her immense cycles; and to eschew that vain self-assertion which sets up the finite and short-lived as capable of grasping and of judging the Infinite and Eternal.

Astronomy.—When Sir John Herschel, bringing safely home his father's great telescope, published the rich harvest of discovery, made under the brilliant skies of South Africa; and Lord Rosse, having constructed, mainly with his own hand, his gigantic reflector, had, even through the misty atmosphere of Ireland, penetrated into the abysses of space, to distances before unheard of, resolving into distinct and widely separated star-groups the hazy nebulæ, supposed before to be but star-dust, the science of astronomy was thought to have done its utmost. For long years to come nothing was to be expected from instrumental means, unless Lord Rosse should follow the example of Sir John Herschel, and transport his large metallic mirror to some bright southern clime. But the risk of damage forbade the attempt; to construct another such in a more favoured clime was not to be thought of. Thus matters stood when hints thrown out long before, and observations made by Wollaston, Frauenhofer, Fox Talbot, Brewster, and others, began to be canvassed again, and ultimately took shape. Chemistry, which had never been in her service before, became, with Optics which had always served, joint handmaid to Astronomy, and gave us a grand and fertile mode of research, whereby we have attained to a knowledge of the constitution of the universe far beyond what the most active imagination had ever conceived. The union I refer to was effected by the spectroscope; and the discovery was, like that of the telescope, very much a matter of accident.

When a beam of light, admitted into a dark room by a small hole or slit, is made to pass through a prism of glass, and a sheet of

paper or other screen is placed behind the prism, a long bright streak, shewing the seven colours of the rainbow, is thrown upon the screen. This rainbow-tinted streak is a lengthened image or spectrum of the sun, and is technically called the solar spectrum. One end is all red, the other all violet, the five remaining colours lying between.

Now, Wollaston long ago noticed that a great many dark lines crossed this spectrum at right angles. The spectrum was not continuous, but broken in many places; at these there was no light of any of the seven colours. Frauenhofer observed these lines carefully afterwards, marked them all off in their true positions, and named them by letters; hence they are called Frauenhofer's lines. Now, as the pitch of musical notes depends on the number of vibrations in the sounding-string, generating corresponding air-waves, so waves of ether, or light-waves of different lengths, sent off from a luminous body, give the sense or impression of colour upon the retina. We interpret, then, the dark lines to mean that light-waves of all the gradations of colour by which red passes into orange, orange into yellow, and so on, do not come to us from the sun; but must be arrested or destroyed as waves somehow, the places of these shades being marked by the dark lines. All this was known; yet no one understood how such arrestment took place. But philosophers did not fail to experiment. They examined the spectrum of the electric light, of white-hot metals, of glowing vapours and liquids, and found certain lines in many of them. A chance observation at last explained all the facts, and bound in one comprehensive law many disconnected phenomena.

In 1859 Kirchhoff was observing the solar spectrum, and noticed that when the sun-light passed through a flame of sodium a certain dark line was intensified. The dark line itself must therefore be due to the sun-light passing through sodium vapour. This vapour must therefore exist in the solar atmosphere. By experiment and reasoning, Kirchhoff now established the principle which is the key to the interpretation of all the phenomena—namely, that whatever rays a luminous body emits, it will absorb rays of the same kind entering into it. The reason is obvious: ether waves of the same *beat* or *period* fall into one another, and are lost as separate waves,—one absorbs the other; while those of different velocities or periods, maintain a separate existence. A beam of any kind of white light—the electric, for example—consists of a ray of yellow, and six of other colours. Pass such a beam through the

yellow flame of sodium vapour, and the yellow constituent is arrested, the other six pass through, and are seen upon the screen, where the place of the yellow is shewn by a dark band. If a flame be employed, containing the vapour of several metals, each metallic vapour will effect the arrestment of some ray, on its own account, and there will be a dark band on the screen corresponding to each. If now we conceive, instead of a beam, a huge globe of electric light enveloped in an atmosphere of flame of several constituent parts, then will this enveloping flame stop all such light-waves as itself emits; and the spectrum received on our screen will want all such rays, will have dark lines, in fact, according to the nature of the substances contained in the flaming envelope. It ought to be remarked, however, that these lines are bands of partial darkness only; they are dark by contrast of the feeble light of the solar envelope with the brilliant light of the nucleus.

On these grounds the sun must be regarded as a body in a state of the most intense heat, and surrounded by a gaseous covering of the utmost brilliance. In this "photosphere" many vapours are present in a state of intense incandescence. These absorb such rays of the nucleus as they themseves emit; and thus Frauenhofer's lines are formed. It has been determined, by examining the spectra of various terrestrial substances, and comparing them with the solar spectrum, what substances are present in the photosphere. Already there have been certainly ascertained to be iron, sodium, magnesium, calcium, chromium, and barium, besides hydrogen in preponderating quantity. These are all in the state of vapour, in fact, volatilized metals; and you will remember that hydrogen, the lightest of bodies, is but the vapour of the metal hydrogenium, the discovery of which, and history of whose properties, formed the last great effort of the genius of the late Master of the Mint.

It must, however, be recollected that many metals volatilize at a temperature not very elevated, and remain permanently in this state. The Torricellian vacuum at the upper part of a barometer tube gets gradually filled with the vapour of the quicksilver, the elastic force of which tends to depress the mercury, and necessitates the application of a small correction. Zinc is driven off from brass long before the copper is volatilized. In copper furnaces, and gold and silver refineries, vapours of these metals lodge in beams at a considerable height, and form crystals in the interstices. How readily, then, may not the intense heat on the sun's surface maintain in a constantly vaporous condition even a metal so obdurate as iron?

The discoveries made by these means in solar physics have been rapid and wondrous, and new and curious points are turning up continually.

[Since these paragraphs were written, it has been discovered that the metallic vapours are confined to the lower portion of the atmosphere, not extending, most probably, to a greater height than 1,000 or 1,500 miles from the sun's surface.]

Over the photosphere there is a second envelope of a coloured substance, considered to be probably 5,000 miles thick, and named chromosphere. Above this, to the total height of probably 850,000 miles, is matter more attenuated, an atmosphere of some thin material, most probably hydrogen; the existence of which is now made out clearly, and which was long ago conjectured to exist by our distinguished member, Professor Grant, when he wrote his *History of Physical Astronomy*, more than twenty years ago.

The "rose-coloured prominences," so often seen round the edge of the moon's disc in total eclipses, were detected in ordinary sunlight without an eclipse, about the beginning of last year, simultaneously by Lockyer in England, and Janssen in India; and the discoveries made known together to the Academy of Sciences at Paris. The spectroscope shews them to be masses of glowing hydrogen, shooting up from the chromosphere like tongues of flame, to heights sometimes of 70,000 and 80,000 miles, and terminating in broken outlines of fantastic forms. The rate of upward motion Mr. Lockyer calculates at forty miles per second; and assuming this, Zollner endeavours to shew that masses of hydrogen are imprisoned at 160 miles of depth below the sun's surface, and that they are liberated by an excess of pressure due to a difference of temperature between the enclosed gas and that free in the sun's covering; and he essays to calculate this difference as amounting to 74,910° C., and the pressure required by the height to be that of 4,070,000 atmospheres. The absolute temperature of the sun's surface he calculates at 27,700° C.

The researches of Wulner in Germany, and those of Lockyer and Frankland in England, have very recently shewn that a glowing gas, which in its ordinary state gives a spectrum of white lines (each vapour having its own set of bright lines), when subjected to great pressure, gives a continuous or unbroken spectrum, like that of an incandescent solid or liquid; and that hence the existence of a solid or liquid glowing nucleus is not necessary to produce such spectra; the light of glowing hydrogen under pressure is intense enough to produce, in an atmosphere of sodium vapour, a Frauenhofer line.

The whole subject is now so rapidly enlarging, that further discoveries must be awaited before we can safely form a theory of the actual constitution of the sun.

The solar spots have been during the whole year developed in great numbers, and of large individual magnitude; and several times during the session I offered some remarks to you regarding them. A few evenings ago, I counted seven or eight large groups—one spot visible to the naked eye, was several thousand miles in diameter. Of the spots we now know very little more than was made known in 1776, by the researches of Dr. Wilson of Glasgow. It is probable, however, that they are somehow connected with the occurrence of storms, like the cyclones of our tropical regions. These would produce horizontal movements as well as vertical, in the gaseous envelopes of the sun, the horizontal transference being at the rate of 120 miles per second, the other at forty miles. The depth of the umbra or dark central nucleus of the spot has been, apparently with some approach to accuracy, determined to be from 2,000 to 4,000 miles below the sun's surface. The first bursting out of these spots is attended with a simultaneous thrill sent through all the magnetic instruments in every observatory in the world, and doubtless influencing the remotest planet.

The Corona or Glory seen round the moon at the time of a total eclipse is now considered as most probably due to the rendering visible of meteoric matter in the sun's neighbourhood—something, in fact, like a solar aurora—but astronomers are by no means agreed; and each succeeding total eclipse is now watched with an interest wonderfully increased.

[Since the above paragraphs were put to press, accounts of the eclipse of December 22, 1870, have reached us, and these shew that the hazy mass or halo, called the corona, consists of two bands of a radiated structure, divided by an irregular boundary all round, the radiations being thus discontinuous, but both sets proceeding outwards in the directions of radii of the moon produced. The *irregularities*, or *breaks*, in the approximately circular boundary between the two sets of radiations, *are coincident with the bases* of the rose-coloured prominences—a new fact, and one of great significance in regard to the connection of these with the corona, and to the action of the sun's attraction on the matter of the prominences, bringing them down again in a sort of parabolic curve. A fact of not less significance is the discovery in the coronal light of the green spectral line of Ängström, before found in the aurora borealis to which reference is made further on. These two interesting facts

regarding the late eclipse have been made known to me while this is passing through the press, by the kindness of Professor A. S. Herschel, and Professor Thorpe, the latter of whom formed one of the Sicilian expedition for observation of this eclipse.]

By applying the new methods and improved instruments, the most wondrous intelligence has come to us from the fixed stars. The elements I have named as existing in the sun, with antimony, mercury, tellurium, and bismuth, have been found in Aldebaran, Sirius, Betelgeux, and most of those which are bright enough to give a spectrum at all. The colours of the stars are mainly due to the effect their atmospheres produce on the passing light. In the same way a planet's light will shew whether it is enveloped by an atmosphere. Their light is solar light, and if the lines in the spectrum remain unaltered, there will be no atmosphere on that planet. It thus appears that the moon is absolutely without atmosphere—as we knew otherwise—and that Jupiter and Saturn have such envelopes, that of Jupiter of great density, and containing some of the vapours and gases found in the earth's atmosphere. In examining the stars, the light is collected by a powerful telescope, and on the *intense spot* thus formed the spectroscope is brought to bear; the lines which this spot shews indicate the substances which are burning in the star. You will no doubt remember that a star on fire was thus detected three or four years ago by Mr. Huggins; *t* of the Northern Crown blazed up to a great size, and shewed brilliant hydrogen lines. In twelve days the size went down from the second to the eighth, a telescopic, magnitude; it burnt down, in fact,—probably from the exhaustion of a hydrogen envelope.

Another marvellous result, quite unlooked for, has recently come out. Mr. Huggins and Dr. W. A. Miller, who observed it first, explained it in this way:—If a tuning-fork is strongly hit, and then rapidly withdrawn, the pitch of the note will vary every moment to an ear at rest—the same takes place with the whistle of a rapidly moving train to a person who is stationary. Now, colour is the *pitch* of light, so to speak; it is given by the length of the waves of ether; light is red when the length of the wave is $\frac{1}{39000}$th of an inch, violet when $\frac{1}{57500}$th of an inch; a change in the colour, or *tone*, will then indicate a greater or less velocity, that is, the number which enter the eye in a second. On these principles it was found that Sirius, the largest star in the heavens, reckoned equal to fourteen of our sun, is moving away from the earth at the rate of 29·4 miles per second, allowance being made for the earth's motion at the time, in direction and rate (19 miles per second), and for the sun's trans-

ference towards Hercules at the absolute velocity of 4½ miles per second. The great majority of the stars have a similar motion in space, a general drift in a particular direction. This drift has been recently separated from that relative displacement due to the sun's motion. The drift, in fact, is quite independent of the sun, and not such as his motion would give; stars, and even whole systems, have really proper motions, like that of the solar system itself. This subject has been lately treated of by Mr. R. A. Proctor in several able papers laid before the Astronomical Society. Maëdler had fixed upon Alcyone in the Pleiades as the centre of the sidereal systems, that to which there was a general star-drift. This is now found to be no more than a local drift. A portion of Perseus is really the centre of many more motions than the Pleiades. But it would be rash to fix as yet upon any constellation as a special centre. How wondrous and complex are the relations thus presented to us! the bare attempt to conceive of them overwhelms the mind.

Many nebulæ were resolved by the Rosse telescope, but many remained irresolvable; of the latter not a few have been found under the spectroscope to be simple glowing vapours highly attenuated, and most probably hydrogen and nitrogen; for though intensely heated, their light is too feeble to indicate their nature with certainty. Of these vast nebular masses, some are moving through space, some are isolated, while others are attached to star-systems, as if to "afford fuel to the burning suns!" Already the great Melbourne telescope, set up last year, has done good service among these nebulæ.

The new method of research has been brought to bear upon comets, meteors, the aurora, and the zodiacal light; but no large comet has visited us since this method arose, and there is still much uncertainty regarding them. That cometary matter closely resembles meteoric there can be no doubt. The meteoric displays of the last two or three years, the impressive grandeur of which passes all description, was caused by the earth's orbit intersecting two concentric rings of meteors, which are in rapid revolution round the sun in a period of 33¼ years. Donati's comet in 1858, and two others in 1862 and 1866, with several smaller, are now known to follow the path of these rings. A comet may thus be but the gathered-up materials of meteors; and matters detached from comets may circulate as meteoric matter till absorbed by the sun as he careers from region to region of boundless space. It is certain that they are highly attenuated, and phosphorescent, rather than incandescent. The marvel is the rapid flight of matter so attenuated, and its resisting, as it passes, the

powerful attraction of the sun. The experiments of Dr. Tyndal on the passage of electric light through highly rarified air containing very minute particles, suggest an origin for the tails, and for their inconceivable velocity of emission. The sun's attraction may bring down matter of some kind in showers of indefinitely small particles; and the illumination of this, as his beams dart across it, may give the appearance of an emission with the velocity required. Though so little of it is visible to us, the quantity of this meteoric and cometary matter diffused through space must be inconceivably great. The two rings are 100,000 miles wide, and 1,000,000 miles in length; and in the perturbations of Mercury there is evidence of an enormous mass of meteorites within his orbit. We have learned but yesterday what an important part they play in the economy of the solar system. The sun himself may be built up of them,—that he is permanently fed by them there seems little doubt, though such supply cannot last for ever; and the discrete masses which circulate round the vast globe of Saturn, appearing to us as three rings, may also be of this same nature.

That the aurora is accompanied by strong magnetic or electrical action there can be no doubt. The experience of observatories and telegraph stations amply testifies to this. It is certainly connected with our atmosphere, the height being often very moderate by which it is separated from the earth, as it is often seen between an observer and a mountain side. It may be caused by electric or magnetic currents passing through rarified air; and may be especially active about the equinoxes, on account of the rapid transmission to our latitudes, at that time, of the rarified air-currents of the anti-trades. It is necessary, however, to observe that the spectrum of the aurora has given a line not known to exist in connection with any terrestrial element. The same line exists in the zodiacal light, and in the envelope of the sun. [I learn, while these paragraphs are at press, that this green line was observed in the spectrum of the corona during the late total eclipse; and this seems almost to establish the identity of the aurora, corona, and zodiacal light, as all consisting of meteoric matter, which contains some element yet unknown to us. Such element may exist as an atmosphere to meteorites, and get mixed with our atmosphere in its higher regions, from the frequent explosions of meteors as they dart through it, and thus shew in the aurora. This recent and important observation has been made known to me by Professor Thorpe.]

The results which spectrum analysis has given us regarding the

constitution of the sun and stars suggest many thoughts of a highly interesting kind. The substances which we find in the sun are the same as those existing on the earth; at least we have no knowledge as yet of any others; and many more of our terrestrial substances may exist there undiscovered by us. This leads to the legitimate conclusion that the planets of the solar system are all of the same structure; for why should one of them agree in this respect, the third in order from the sun, and the rest differ? We know they have atmospheres, clouds, and mountains; and in regard to Mars, that he has continents and seas. Clouds, mountains, and seas imply the existence of lakes and rivers! Are all these substances, these arrangements, the manifestations of great natural laws in operation, only placed there, made, or acting, that we may observe, speculate, and admire? Are not all these bodies the abodes of plants, animals, and higher intelligences? Doubtless they are inhabited; and the lime, the magnesia, the iron, zinc, cobalt, copper, antimony, and hydrogen, as well as the air that surrounds the planets, are placed there for purposes of use. Thus the discoveries of the spectroscope lend vast additional weight to the arguments which were urged, as you will remember, by Sir David Brewster, some years ago, against those of Professor Whewell, for the existence of other inhabited worlds, the moon of course excepted; for, so far as we can judge, her surface shews us a world in a state of utter physical ruin.

That these same substances have been found in all the fixed stars which have been examined, renders the conclusion very forcible for a like structure of the planetary orbs which circle round them, and for the argument that these also have not been made in vain, but are the abodes of countless millions of intelligent beings, living for the glory and the delight of their Creator. Again, whatever may be the general support which an intelligent philosophy gives to the nebular hypothesis of Laplace, on physical grounds or mechanical principles, or its consistency with the actual structure of the universe (of which there is the utmost doubt), the spectroscope has certainly shewn us that nebulous matter still really exists, and that clusters are irresolvable, not because our instruments want power, but because there are really no stars to see there; but merely an attenuated gas, of a simple structure, existing in masses of inconceivable magnitude in various parts of space.

Geology.—I have occupied so much of your time already, that I must now confine myself to a very few remarks on the recent progress of Geology.

The discussions in regard to the age of the crystalline schists of the central Highlands, between Sir R. Murchison and his supporters on the one hand, and Professor James Nicol on the other, has in the meantime come to a close. The tone of some of the later papers had become too keen, and Professor Nicol, unwilling in any way to increase this acerbity, has forborne a rejoinder. His views he declares to be unaltered; he even assures me he has many new and important facts to bring forward in support of them, which are for the present withheld. The question can thus hardly be regarded as quite settled, at least in the minds of many who regard Professor Nicol as a physical geologist of great ability, and possessing an intimate knowledge of the whole region which is the subject of dispute. But I shall not follow this subject further, as I may have something to say upon it in the course of this session, having twice visited of late some of the controverted sections.

The discussion on the nature of the so-called oldest fossil of the globe, the Canadian Eozoon of the Laurentian rocks, is as vigorously carried on as ever, Dr. Dawson and Dr. Carpenter still maintaining its organic character, while Professors King and Rowney as stoutly support the view of its mineral origin. Some new facts were brought up at the last meeting of the British Association in Liverpool. Professor King presented a specimen of altered lias-marble from contact with syenite near Broadford, in Skye, a locality which I know well, and described it as possessing, in as marked a degree as the Canadian specimens, the peculiar structure, even in the microscopic features, which distinguish the Eozoon of the Laurentian rocks. If this could be established, the inorganic character of Eozoon must be admitted at once. Dr. Carpenter was not present, and the subject excited little discussion; for, after all, it is very much a question of microscopic examination, without which few would wish to venture an opinion. From all I could gather, however, in conversation with the geologists present, opinions seemed to be nearly equally divided. Professor Rupert Jones, a well-known microscopist, supports Dr. Carpenter's view, and Sir Charles Lyell, himself a host, accepts the Eozoon as a true fossil. If so, then is the existence of life on the globe carried down, as Sir W. Logan observes, as far below its former horizon in the Cambrian beds, as these Cambrians are distant from the chalk, or lower tertiaries. Thus is the age of life on the globe doubled at once, and an ample lease of time granted to the advocates of the theory of evolution, wherein a progressive development, and modification of organic forms from lower to higher types, may be worked out.

Geology has always seemed to me to be wholly opposed to any theory of evolution. It shews that the same organic forms have maintained a striking permanence through many successive formations, and intervals of time so vast, that the mind fails to grasp them. Of this persistency of organic forms instances might be multiplied. Certain fossils of the Silurian period cannot be distinguished from species now living; while in the genera and species of this great formation, which represents a vast period, there is as great diversity of forms as in our living fauna. Here the family of Trilobites, now extinct, and which had then its great development, presents to us, as Mr. Gwyn Jeffreys has shewn, many points of departure in the variations, and not a *single point* from which they proceeded. A large assemblage of species disappears at the top of a certain Welsh group, and after an interval of 5,000 feet of strata is passed through, the whole assemblage appears again in the same specific forms. Two species of lizard have lately been obtained from the new red sandstone of the north of Scotland; but they are wholly unlike one another, and unlike any lizard of the Permian or Triasic formations; one of them, the Telerpeton, is "in structure, economy, and physiognomy," in fact, "in every respect exactly like a modern gecko," as perfectly organized, and without a single character approximating it to the reptiles of beds below; from all Lacertians, recent and fossil, it differs in the structure of the fifth digit of the hind foot. The other creature, Hyperodapedon, from the same beds, has no analogy with the last, but resembles in the closest manner a lizard still living in New Zealand (Sphenodon). Both have a structure of jaw which belongs to no other reptile, living or fossil.* This fossil lizard has been found in similar beds in England, in India by Dr. Oldham, and in South Africa remains of the same genus have been discovered.

The doctrine of the permanency of organic forms has received striking confirmation in the results of the dredging expeditions in the Atlantic just brought to a close. The floor of this ocean, from the Faroe Isles to St. Helena, and from the coast of Ireland to Florida, at depths from 3,000 feet to three miles, is covered with a deposit of calcareous mud, which, when dried, has a close resemblance to chalk or oolite, and like the ancient chalk, itself a deep-sea deposit, consists, wholly in many parts, of microscopic organisms; the entire mass being penetrated by a living organism of a gelatinous structure, which has the power of separating from sea water lime, and such organic compounds as supply food to the minute

* Huxley, in *Jour. Geol. Soc.*, vol. xxiii., 1867, p. 77; and vol. xxv., 1869, p. 167.

Globigerinæ, whose broken shell-cases make up the great mass of the ooze or mud. On this white chalky mud there were found, flourishing in abundance, many species of sponges, echini, crustaceans, and mollusks, the entire assemblage forming a marine fauna with a great general likeness to that of the ancient chalk period, though whole groups, as the Ammonites, Hippurites, Baculites, &c., with the fishes, are unrepresented in the dredgings. Of those which are living, a considerable number of species are identical with those which are fossil in the chalk, and were till now considered to be extinct. Through the vast lapse of ages which separate our time from the epoch when the white chalk began to be deposited in a deep-sea area reaching from the north of Ireland to South Russia, and from the Pyrenees to Moen in the Cattegat, these creatures lived on, unmodified by the changing conditions, and surviving the revolutions which destroyed the chambered cephalopods; for

> "The Almighty's breath spake out in death,
> And the Ammonite lived no more."

What more striking example could be given to illustrate the truth of the permanency of forms, and the stability of the laws of their existence impressed upon these creatures when first called into being?

Another most striking fact brought to light by these dredgings is the existence of a warm and cold area, within six miles of one another along the sea bottom. The water in the warm area has a temperature of 45° to 48° F.; that in the cold from 30° to 32° F. The fauna of the one is of an arctic character, that of the other warm-temperate, and it is not a little remarkable that the mineral character of the deposits is essentially different in the two areas. The bearing of these facts on the conditions and character of cotemporaneous formations, and on reasonings regarding surface changes of climate, is too obvious to require further remark.

Some have alleged that the generalizations of geologists are discredited by these discoveries, and that their conclusions will need to be modified. But this is a hasty view of the subject. Geology stands fast as a science on two generalizations, which nothing can now disturb:—1st. That the crust of the earth is built up of strata, which have a certain regular succession, never departed from, and the same in all countries; and, 2ndly, That these strata, if fossiliferous at all, are characterized by like assemblages of fossils, and can be identified by these over vast distances, though mineral characters may fail. When it is said that we are still living "in

the chalk period," this is meant perhaps merely as a figure of speech, or period may be confounded with formation. The creatures of the ancient chalk, which survive in the Atlantic, are but a small part, and that the less highly organized, of the animal remains of the chalk period; whole groups passed away with the close of that period, and are, doubtless, nowhere represented on the face of the earth; new groups were introduced to take their place, and a new life-period inaugurated; new races arose, new geographical and climatic conditions were established, revolutions commissioned to do their work, and thus the tertiary periods were made up. There would be more countenance for the assertion, that a certain cycle has come round again, under new conditions, and that we are living now in a colder period, in which a chalk formation is in progress, a period less prolific of life, but preserving some most precious evidences of an older life-period, prevailing even more widely, and attesting to the grand truth that organic forms have a true inherent permanence, o'ermastering the power of outward circumstances, and proclaiming ever as they flourish and live on—

"The hand that made us is divine."

It was not till several weeks after this address had been delivered before the Society, that I read the last address delivered by Professor Huxley, as President of the Geological Society.

He examines at some length the geological evidence in support of the evolution hypothesis, and admits its failure in so far as the invertebrate and lower vertebrate animals are concerned:—"For anything that as yet appears to the contrary, the earliest known Marsupials (middle oolite) may have been as highly organized as their living congeners; the Permian Lizards shew no signs of inferiority to those of the present day; the Labyrinthodonts cannot be placed below the living Salamander and Triton; indeed, the Labyrinthodont fauna of the Carboniferous rocks is more extensive and diversified than that of the Trias, while its chief types are quite as highly organized. Thus, it is certain that a highly organized vertebrate type is capable of persisting, with no considerable change, through the period represented by the vast deposits which constitute the Carboniferous, the Permian, and the Triassic formations." And, again, he remarks,—"The significance of persistent types, and the small amount of change which has taken place, becomes greater and greater in my eyes the longer I occupy myself with the biology of the past. . . . Even in the Miocene epoch, every important group in every order of the

mammalia was represented, . . . and even the scanty Eocene fauna yields examples of all the orders; while, if we go back to the older half of the Mesozoic epoch, every order of the Reptilia is represented, except the Ophidia, and groups abounded *more specialized* than any which now exist."

These remarks have all the same bearing as those contained in the preceding paragraphs, although they were unknown to me when those paragraphs were written. The important bearing of the Atlantic dredgings Professor Huxley also freely admits; and, in that straightforward manly style which was to be expected from him, acknowledges the difficulties which beset the evolution hypothesis; yet is he by no means inclined to give it up. On the contrary, he remarks, "in regard to the higher *Vertebrata*, the results of recent investigations, however we may sift and criticize them, seem to me to leave a clear balance in favour of the doctrine of the evolution of living forms one from another;" and he then enters on a long discussion of the evidence to be derived from the intermediate forms among the higher orders of this class, *the lower orders and the whole invertebrate fauna furnishing no evidence.* I cannot pretend to follow Professor Huxley into this discussion, but I would remark that it seems strange that if evolution was the law of life, and not successive creation, there should be so many cases of persistency of form through the immense periods acknowledged by all, and no evidence to be drawn, even by "one who would have been glad to be able to find a good foundation for the doctrine," from the vast suite of formations, and all the varied forms of animal life entombed in them, till we reach the higher types of vertebrata in the upper beds.

But if we allow the inferences in regard to modification of form,—and, no doubt, within certain limits which are related to the constitution and vital force of each particular species such modification must be admitted,—we must look for some cause which determined the change at first. For such origination, neither "Natural Selection," nor any other theory of development, pretends to account. They deal only with the changes after they are produced. "Why," then, "should it be thought a thing incredible with" any evolutionist that a Presiding Intelligence, foreseeing the new external conditions under which an organic being was to be placed, and the purpose it was to serve, as in the case of the Horse so fully gone into by Professor Huxley, should give the organic forms such direction as to harmonize the structure in its development with those foreseen external conditions? This is the view of the operation of

Creative Will in originating new forms, very fully and eloquently set forth by the Duke of Argyll, in his most able work, *The Reign of Law,* in which the 1st and 5th chapters treat at length of the subject of natural selection, especially in its bearing on Geology. A suggestion somewhat to this purpose was offered by Professor Owen, as stated by the Duke of Argyll, some years before the theory of natural selection was promulgated; it had reference to the early appearance of forms approaching to the Horse and Ox—which were destined to be the servants of man. Now, if we consider the established facts regarding the *total extinction* of many forms of life in the geological sequence, the appearance of new forms to supply their place; the evidence, "which no sane person can doubt," for Man's introduction to the abode prepared for him by an act of Creative Will, and the universal inward consciousness which revolts from the idea that Man is a *specialized* brute; I would go farther, and maintain "that species were separately constructed, out of dust, or out of nothing, by supernatural power," as Professor Huxley thinks "conceivable;" but "will not admit it till he receives distinct evidence of the fact." What evidence would be satisfactory to him he does not indicate, and we need not attempt to conjecture. The instincts of our nature in regard to our relations to the Supreme Being in the future, and the destinies of the race, ought to reckon for much as evidence to any mind.

II.—*Note on Stevenson's Light for Ships.* By Mr. James R. Napier.

Read before the Society, November 16, 1870.

Mr. Thomas Stevenson, the eminent light-house engineer, having kindly lent the Society a duplicate of one of the side-lights of the steamer "Pharos," fitted with his azimuthal condensing apparatus, it was lighted and explained by Mr. James R. Napier, who again called attention to the danger of collisions at sea from vessels' side-lights being seen across the bow, instead of only from right ahead, as required by law, and stated that although the Board of Trade had improved their instructions since he directed their attention to the subject, in 1867,* they still left something to be done; and that ship

* *Transactions of the Institution of Engineers in Scotland*, November, 1867; October, 1868.

owners who looked to their own interest would prefer the parallel lights of the Act of Parliament to the crossed lights of the Board of Trade. Mr. Stevenson's apparatus had the merit of almost literally complying with the Act, without the screen prescribed there, and of sending nearly all the light of the lamp in the required direction. It was costly, no doubt, but as nothing to that of a big ship; and it might be simplified, with probably very little loss of effect.

III.—*The Farmer and the Chemist.* By MR. JAMES NAPIER, Sen., F.C.S.

Read before the Society, November 30, 1870.

IF I am asked the question, Why not read this paper to the Chemical Section of the Society? my answer is, There is nothing in the paper that is novel to the professional chemist, and also, that my remarks will embrace the commercial as well as the chemical relations of the parties named in the title, and will therefore be more suited to the whole Society than to any special branch of it, the branch being included in the whole. I shall take the liberty of introducing the subject in the most elementary form. There is an old and still common division of matter into what are termed the three kingdoms of Nature—namely, animal, vegetable, and mineral. Philosophers have long pointed out a wonderful harmony existing between these three divisions, especially between the two forces that are ever in operation upon the mineral—viz., vegetable and animal life. The true relations of this harmony, however, are not always apparent to the popular mind. If, for example, it was the sole delight of one neighbour to build up erections, and the equally sole delight of his next neighbour to pull down what the other had built, we would hardly expect them to live in harmony together; yet this represents the harmony existing between the animal and vegetable kingdoms. The vegetable is constantly building up and restoring; the animal is burning up and destroying that which the vegetable has built; and this may be stated in detail as follows:—

1. A vegetable is an apparatus for construction, and is fixed.
   An animal is an apparatus for combustion, and is locomotive.
2. A vegetable transforms mineral matter into organic matter.

An animal transforms organic matter into mineral.

3. Vegetables derive their elements from earth and air.
   Animals give their elements to earth and air.
4. Vegetables produce oxygen, starch, sugar, gum, and fats.
   Animals consume oxygen, starch, sugar, gum, and fats.
5. Vegetables inhale carbonic acid, water, and oxide of ammonia.
   Animals exhale carbonic acid, water, and oxide of ammonia.
6. Vegetables reduce these compounds.
   Animals make them.

Such is a detailed and popular view of the harmony existing in the three kingdoms of Nature, which, if borne in mind, will aid us in appreciating the relations of the farmer and the chemist. And I may ask here, in passing, How is it possible, from these relations, that a vegetable could ever, by any transformation, be developed into an animal, even starting from a protoplasm? There must be two distinct and antagonistic forces, each operating in its own way.

Having stated these fundamental principles, it may be asked, How far man has control over this harmony of the three divisions of matter? Viewing the subject as a whole, it may be answered, None; but, taken locally, he has a large control; and I will endeavour to make this apparent by a simple illustration, which will bring us to the main subject of this paper. I daresay most of my hearers have, when young, caught little fish, and placed them in a dish with water to keep them alive, but were grieved to find that the fish died after a day or two, and have blamed everything as the cause but ignorance. It is now well known that, by putting into the bottom of the vessel some soil, a few roots of water-grass, and a few snails, the water is kept pure, and the fish are preserved in life. This constitutes a simple aquarium; but the keeper of this aquarium has to watch and regulate the harmony of the group. If the snails are too numerous for the grass, some of them have to be removed; if the grass be too luxuriant, more snails have to be added. The grass feeds upon and takes up the dung and carbonic acid given off by the animals; and it in return supplies oxygen for the animals to breathe; and thus the water is kept pure. Now, the keeper of this aquarium represents the farmer of the olden time—even of half a century back—when all the animal refuse of town and country found its way back to the soil of the farm. But suppose that the snails and fish in our aquarium were to resolve that all their refuse matter henceforth should be kept from the water they live in, and take means to put it elsewhere, the result would be a breaking up of the harmony of the group, both plants and animals would sicken and die, and the

aquarium keeper would be driven to his wits-end. He would thus represent the position the farmers would have been in at present, if left entirely to their own resources; but the chemist came to the farmer's aid, and he found out, by a series of investigations and analyses, the composition of the different plants grown by the farmer—that the component parts of every kind of plant were constant, although varying in quantity in different kinds of plants, and that although some of the earthy components were in very small quantity, still they were as essential to the health and growth of the plant as those parts that were in greater proportion; also, that the sources from which the vegetables received these component parts were the soil, the water, and the atmosphere; that in order to the full development of plant life there must be, not only a sufficiency of every ingredient necessary for it, but also in a condition fit for the plant to feed upon; and then, by analyzing the matters of which our social arrangements had deprived the soil, he was enabled to direct the farmer to new sources of supply. In this way the chemist and farmer became mutual helpers, both for personal and general good, and at once raised the business of a farmer from being a mere routine of processes requiring little skill, to a profession requiring a liberal education, embracing an intimate knowledge of different sciences, especially of theoretical and technical chemistry. But farmers are not yet chemists, and the mere knowledge of what is necessary does not help them much. Under these circumstances, however, there has arisen a third party, who undertakes the supply of all these wants of the farmer. This is the artificial manure-maker, who may know little or nothing of either chemistry or farming. Although the farmer has come to the knowledge that every plant has its own wants, and that the soil is the principal medium through which these are supplied, still he is ignorant of what his soils contain, and consequently does not know what special plant-food his soil is deficient in. The manure-maker knows as little of the special want of the farmer as he does himself, but generally acts thus,—having learned the constituents of the plant, he makes up a mixture containing something of each, which being added to the soil, the plant may select what it requires. Some, however, are more definite in this matter, and offer special manure for turnips, potatoes, cereals, &c., &c.; each and all are thus patronized by farmers. It often happens that two farmers buy the same kind of manure, and apply it to the growth of the same kind of plant. One has a wonderful crop, and in gratitude sends a glowing certificate; the other has a failure, and blames the manufacturer for cheating him, and threatens law for redress, and buys somewhere else next

season; and this, less or more, has gone on for years. Surely this is not a very healthy state of trade; and the question is, Who are to blame? I blame no one, but merely say that, where there exists such an amount of ignorance, both by the seller and buyer, of what is really required, there is room for empiricism. If the farmer of the present day cannot help himself, it will at least teach him the duty of educating his sons, who are to follow him, that they be qualified to test the condition of the soils and know what is required for the plant. While, however, an intimate knowledge of chemistry is essential, it must be accompanied with practical experience of farming. There is much truth in the adage that an ounce of practice is worth a pound of theory; but, at the same time, there is no truth in the statement that theory and practice are in conflict with each other. Where they seem to jar, there is either something false in the theory or wrong in the practice: and this applies forcibly to the farmer in relation to chemistry; but the farmer and chemist should be one person, or, at all events, should have one interest. The farmer should become as familiar with the composition of his soil as a merchant with the stock of goods in his warehouse—the contents of the soil being to him a large portion of his stock-in-trade—so that when he takes off one crop from a field, he should know from the weight of the crop removed what ingredients the soil has been deprived of, and, consequently, what will be necessary for the next crop to be sown; and then let him send to the manure-maker or chemical manufacturer for such ingredients his crop and soil require. Until he can do this, the farmer is not master of his trade, but is carrying it on at haphazard. Knowledge in trade is more than power—it is profits. If this was kept more in mind, there would be more seeking after it.

I have confined myself as yet to the relation of the chemist and farmer, as mutual helpers in working out the fundamental principles of the art of the agriculturist. I now draw your attention to another phase of this relationship, which has grown up during these years of transition, and which is not so pleasant nor gratifying to the chemical profession,—I mean, the commercial position between the chemist and farmer at the present time; and by the term chemist here, I do not mean such as those I have been referring to, who carefully investigate the various changes that take place between the plant, the soil, and manure, and their relations to each other—these are the true guides of the farmer, the patriots of the country; but I refer now to the commercial analyst who professes to give the ingredients of a sample of manure for a small fee.

That bones fertilize a soil, was known to the ancients; but it is comparatively a short time since it was known that the cause of this fertilizing property depends upon the presence of phosphoric acid and nitrogen. The basis of bone is a compound of three proportions or equivalents of lime, and one equivalent of phosphoric acid—keeping by the old notation: thus,—

$$\left\{\begin{array}{l}72.\ \text{Phosphoric acid.}\\ 28.\ \text{Lime.}\\ 28.\ \text{Lime.}\\ 28.\ \text{Lime.}\end{array}\right.$$

This compound of bone is insoluble in pure water, but slightly soluble in water containing carbonic acid, and more so if gelatinous matter is present. Hence raw bones are very good fertilizers. When the gelatinous part of bone is burned away, leaving the carbon, it is called bone-charcoal; when both are burned away, the residue is termed bone-ash. In both these cases the phosphate of lime remains unchanged, and is still slightly soluble in the soil by water containing carbonic acid,—some say not so easily, others, more easily than raw bones,—varying in any case very much according to the nature of the soil, but even under the most favourable circumstances requiring, if applied in proper quantity for fertilizing, years before they are fully decomposed and in fit state to be taken up by the plant; so that to keep a soil in a highly fertilizing condition, by the application of bones, will require the constant presence of a large quantity in the soil, and, consequently, a large sum of money lying unproductive.

Here, again, the philosophic chemist came in aid of the farmer, by pointing out that if these bones are acted upon by an acid, such as sulphuric acid in certain proportions, it takes up some of the lime, and loosens, if we may use the expression, the phosphoric acid, leaving a compound of it and lime, easily soluble in water. Thus,—

$$\left.\begin{array}{l}72.\ \text{Phosphoric acid,}\\ 28.\ \text{Lime,}\end{array}\right\}\ \text{Phosphate of lime, popularly known as biphosphate.}$$

$$\left.\begin{array}{l}28.\ \text{Lime,}\\ 28.\ \text{Lime,}\\ 40.\ \text{Sulphuric acid,}\\ 40.\ \text{Sulphuric acid,}\end{array}\right\}\ \text{Sulphate lime.}$$

The phosphoric acid in this biphosphate is in a condition to feed the plant immediately; so that the farmer, knowing, as he should know, the quantity of phosphoric acid required by the plant he intends to grow, can apply that quantity, and thus not only save

capital, but have a return for the money he lays out in one year. The manufacture of this superphosphate is the business of the manure-maker.

In a very few years after the manufacture of these soluble phosphates was introduced, the demand for them increased beyond the supply of bone-material to make them. Consequently other sources of phosphates of lime were sought for, and found in the mineral kingdom—such as coprolites, apatite, and a variety of different minerals having somewhat similar composition. These were got much cheaper than bones; and, we think, unfortunately, instead of their being introduced as a substitute for bones, and sold to the farmer at a fair price as such, they were introduced mixed with bone-phosphates as adulterants, and the mixture was sold as dissolved bones, or bone-superphosphates. This has led all the parties concerned into a false position, one of constant jealousy and want of confidence in one another. The extent of this adulteration I cannot pretend to judge; but, looking at manufacturers' circulars, I am afraid that the suspicions of many farmers, of extensive adulterations of this sort, are too well founded. In 1869, the import of bones and bone-ash, for all purposes, amounted to 95,979 tons; and, according to a statement made last session, by Mr. Hutton, in the Chemical Section, there were 200,000 tons of mineral phosphates raised in this country alone last year; and if we include what comes from America and the Continent of Europe, we are safe enough in saying that the quantity of minerals used is three times that of the bones. It may be said here, that if the substances are of the same composition as bones, and have the same relative manurial value, the adulteration is really serving the wants of the farmers without shocking their prejudices, as they all prefer the bone-material; but the comparative manurial value between bones and mineral phosphates is not yet determined. The belief is, that mineral phosphates, that have not been acted upon by an acid, have no manurial value whatever, or, at all events, very little; and this is practically confirmed by some large manufacturers professing to charge nothing for mineral phosphates that have not been rendered soluble by the acid. Whether, when these mineral phosphates are rendered soluble by an acid, they are of equal value with a bone-phosphate, also soluble, is a question not yet determined. Chemically speaking, I do not see the difference; but practically, the farmer has doubts about this; and as he is seldom sure, when he buys bone-phosphates, whether they are mixed or not, he is not in a position to determine practically their relative manurial values. The question naturally

suggests itself, Why don't the farmer apply to his friend the chemist to guide him in his purchases, and tell him whether he is getting bones or minerals? and, if mixed, in what proportions? I certainly think it is within the compass of the careful analyst to discriminate between a bone and mineral phosphate, and also to determine whether a bone-phosphate is mixed with a mineral phosphate; but from my own experience, in having samples analyzed, and from observations, embracing nearly 200 so-called analyses of manures, I am compelled to say that there is very little confidence to be placed in the results; and I say, unhesitatingly, that when the substances are in a soluble condition, and when the analyst pretends to tell whether they are derived from bone-ash or mineral, or both, I have not the slightest confidence in the decision—that is, according to the ordinary system of commercial testing. We have had samples made entirely from bone-material reported to have four-fifths of mineral, and we have made up samples having three parts mineral, and had them reported all bone; nay, samples of entire mineral have been reported entirely bone-phosphate. But not only in the matter of detecting a mixture of different phosphates, which, I admit, is difficult, and requires great care, but in determining the quantity of phosphate of lime in any sample, whether mixed or not, there is a grievous want of accuracy. We have sent a portion of the same lot of dissolved bone-ash, just as dissolved, to four different chemists, or analysts, and they differed in the phosphates from 41 per cent. to 47 per cent. The mean was nearly what should have been; but a round-about way to get at the truth, even in pure bone-ash, when samples of a cargo are taken with great care, and thoroughly mixed. The two analysts seldom come closer than between 2 and 3 per cent. of the phosphates; at least, this is our experience. We have seen 5 per cent. of difference. As these are purchased by the percentage of phosphate of lime present, differences of this sort lead not only to grave suspicions of want of care, but great loss of money. I am afraid the claim for chemistry being one of the exact sciences, would sound doubtful in the ears of farmers and manure-makers, and any person not a chemist. Our experience, after a few years of manure-making, is, that there is a great want of care, not only in the mechanical manipulation, but in drawing up the result of an analysis; for when the careful chemist is working upon known compounds, he can tell by the results where there is any great error, and whether it represents what the substance was said to be; for example, in analyzing a superphosphate made from bones, he knows the fixed composition of the phosphate of lime in bones, and the reactions

that take place by the adding of the vitriol, and, consequently, that for every 100 parts of biphosphate made, there must of necessity be found 136 of sulphate of lime; and, as this is generally given by analysts as hydrated sulphate of lime (gypsum), then there must be 172 gypsum for every 100 of biphosphate. Thus,—

72.	Phosphoric acid,	100 Biphosphate.
28.	Lime,	
28.	Lime,	172 Gypsum.
28.	Lime,	
40.	Sulphuric acid,	
40.	Sulphuric acid,	
36.	Water,	

With this knowledge, if a chemist, analyzing or making up an analysis of what he got as bone superphosphate, found the hydrated sulphate of lime in less quantity than the biphosphate got, he would suspect something wrong, re-examine his sample, and if the analysis was correct, draw the attention of his client to the matter. I have a list of analyses published by a Farmers' Club, where a bone superphosphate has less hydrated gypsum than biphosphate in it, and without remark. However, this was a sample sent for analysis by a manure-maker; but no samples sent by farmers, that had been bought from the same maker, came near it. Apart from the commercial view, such samples as this are worth attention, for the sake of science; because, if there were any truth in its being a bone superphosphate, bones of such a composition would be new to natural history, and to find out the animals that produced them would be an important discovery. Indeed, if the naturalist was to look at the analyses of bones sold for manure, his curiosity would be greatly excited. It is but recently since we had a bone-ash analyzed where 9·5 per cent. of the phosphates were stated to be phosphate of magnesia. Here was a new discovery before our eyes; and although it cost us dearly, still, it would have have been worth any money; but, unfortunately, in testing other portions of the cargo, we could not find the magnesia, and our hopes were dispelled.

There is another and rather a serious position which the commercial analyst has assumed in relation to manures, no doubt originating in a laudable desire to help the farmer; but it has turned out a source of great annoyance, injustice, and ill-feeling between the manure-maker and the farmer. I refer to the practice of the analyst fixing a commercial value upon the different components found by analysis, without any respect to the real market value of any of the

ingredients, and certainly having no relation to their manurial value to the farmer; because, as I have already said, this relation depends upon his wants. Besides, different chemists give different rates of valuation, ranging from 7 per cent. to 50 per cent., without any apparent reason. I will state two examples: when the market price of phosphates in bone was £6 per ton, the average price by the chemists for soluble phosphates was £27 per ton. Now, when the phosphate of bones are £50 per cent. dearer, the price of the chemist's is £22, nearly 20 per cent. less; and in valuing, no distinction is made between soluble bone and mineral, although the latter is from 40 per cent. to 50 per cent. cheaper in the market. My second example is more anomalous. I have stated that raw bone has a considerable manurial value, from having, in its organic portions, nitrogen. Skins, hair, leather, wool, hoofs, &c., &c., have also large quantities of nitrogen. When any of these matters are in the manure, the analyst values the nitrogen as ammonia, taking the equivalent it will make. Now, ammonia is a manufactured article of very high value in the market; and consequently, to value the nitrogen existing in such matters at the same rate at which it would be sold as ammonia, after an expensive and tedious process of manufacture, is, to say the least of it, absurd; and no merchant who knew his business would submit to it. There is, however, large quantities of ammonia used in manures as sulphate of ammonia, and such should be valued as a manufactured article; but even when this salt is present, the chemist's valuation is altogether out of the rule of ordinary trade. When ammonia was selling at £45 per ton, the average value put upon it by the chemists was £58 per ton. Now, when ammonia sells in the market at £68 per ton, the average price put on it by chemists is £65. We believe that some of our chemists are beginning to see the evil of this practice; but the system has become so conventional, that the object of most of the farmers who send their manure to be tested is in order to compare the money value of the chemist by what they have been charged, rather than to know its manurial value. Now, the analyst knows perfectly well whether the ammonia exists in the manure as a manufactured article, or merely having the raw material, and the not drawing the attention of the farmer to the difference, an injury is done to him in two ways: first, by his paying ten times the value for it; and second, if it exist as ammonia, and he pays only its value, he gets that returned in one season, but if as nitrogen in leather, hair, &c., he won't get the value returned by his crops for several years, and may suffer a greater loss in crops than the whole cost of manure.

You will observe that this loose system of chemistry and valuation is a premium on adulteration, so that both the farmer and the honest manure-maker have need to be protected from this kind of chemical umpireship.

From these remarks one would almost be inclined to suppose that chemical science was at a discount, and falling from its deservedly high position. I have no such thoughts; I am referring to the abuse of it, and the false position it has assumed, which is bringing the science into discredit. But why should it ever get into this position? One cause, I think, is, that the chemist must have bread and butter like other ordinary mortals, and when his science has to be used as a means of procuring this—as a trade—it must come under the same law of competition as other trades; the analyst must do the work cheap, and in the cheapest manner, in order to make it pay. Not only farmers, but the public generally, have very misty ideas of chemistry in a commercial aspect. Farmers have shewn this to a very great extent. They have no doubt been placed in a novel position, in which they have felt their own helplessness; and in order to protect themselves from spurious manures and other sources of imposition, they have formed themselves into clubs and societies to get chemical aid. One chief aim of many of these clubs is to cheapen analyses to the members more than to get correct analyses. A common practice of these clubs is to give a Professor of Chemistry a certain salary, in order that he may perform analyses for the members at a cheaper rate than to the public,—somewhat like a parish paying a doctor a fixed salary for attending paupers. Why, the salary being secure, the fewer analyses he gets from members, and the cheaper they are done, the better it pays. If this money paid as salary were given to those members who sent analyses to enable them to pay a third or half more for their analyses than the ordinary price charged, the commercial chemist would pay extra attention to such customers, and assist them, by their information, to retain their business. It is thus a considerable object in a commercial analyst to get a connection with a farmers' club. We know a Professor who offered to do 100 analyses for a club, this last season, for the small sum of £20. The club thought to do better, and engaged their chemist, as they would their tailor, to come to the house, or to their locality, and make up the analyses there. They certainly had their analyses cheap, so far as money was concerned, but the result shewed how helpless farmers are in their new condition. Out of 75 samples analyzed, 30 were sent in by manure-makers and their agents, and serve as advertisements for next season, and appear as if

by the authority of the club. Amongst the 30 are analyses the most extraordinary that ever came under our notice—I should say, chemically, humiliating. The club being threatened with damages for publishing false analyses and valuations, withdrew their first publication, and appointed a small committee of farmers to revise the chemist's report. The whole proceedings seemed beyond explanation, until we found the solution in the fact that the club is managed under the influence of several persons connected with manure-making.

Without going further into the anomalous relation of the farmer and commercial chemist to the manure-maker, I would tender the following suggestions. First, to the farmer. I would say, You have been using, unknowingly, mineral phosphates to a large extent, and you must make up your mind to continue to use them, probably in a larger extent than ever,—the demand for artificial manures, and the limited supply of bones, force this upon you without choice. Let your aim therefore be, to find out the relative manurial value of mineral and bone phosphates, soluble and insoluble, and also of the other ingredients existing, and as they do exist, in the manure. This being ascertained, you may safely leave the commercial value to the ordinary competition of trade. Let no third party interfere in this matter.

And, second, to the manure-manufacturer we would say, Tell the farmer honestly, who buys from you, the relative proportions of each bone and mineral in the manure he purchases; also the source of the ammonia; and this will enable him to find out their relative manurial values, which will ultimately tend to mutual advantage. If this advice won't be put into practice, the farmer in the meantime cannot better himself. There are only two other remedies for the evil; the one would be a sad reflection upon our character as honest men—namely, to apply to Government to do as they did with the mixing of chicory and coffee. The second remedy is, to convert all the manure-manufacturers to Christianity! When that takes place, there will be a harmony between the chemist, farmer, and manure-maker that does not exist at present.

DR. WALLACE remarked that Mr. Napier's paper might be divided into two parts, the chemical and the commercial. As regards the purely chemical part of the paper, he complimented Mr. Napier in having given an excellent resumé of the principal facts connected with the chemistry of agriculture. He could not see any difference in value between "biphosphate" of lime, whether

made from bones, bone-ash, or mineral phosphates, although, no doubt, the prices of the raw material were very different; but he considered that insoluble mineral phosphates were of little value to the farmer. The commercial part of Mr. Napier's paper related to analytical chemists and their fees, and he could only say that he cordially indorsed the views set forth in the paper. Cheap analyses, like other cheap commodities, were generally of little value. Men in all ranks of life must be adequately remunerated for their labour, and bargain-hunters were rightly served if they got reports which, instead of being useful to them, only led them astray.

Mr. Tatlock said he believed the discrepancies between the results obtained by different chemists were due, in a great measure, to the incompetency of amateur analysts, whose analyses were frequently, but very improperly, compared with those of professional men of long standing. He believed that many merchants and farmers were under a misapprehension regarding the nature of chemical analysis, supposing that the processes were easily acquired, whereas much skill and experience were usually necessary to ensure accuracy. He did not consider it possible, by chemical means, to determine absolutely, in all cases, whether any particular sample of manure was made partly or entirely from mineral phosphates, and thought chemists should not offer any opinion on this point. Mr. Napier had very properly represented that one cause of inaccuracies was the inadequate fees that were usually paid for analyses which represented much labour, time, and skill, and had justly deprecated cheap chemistry generally.

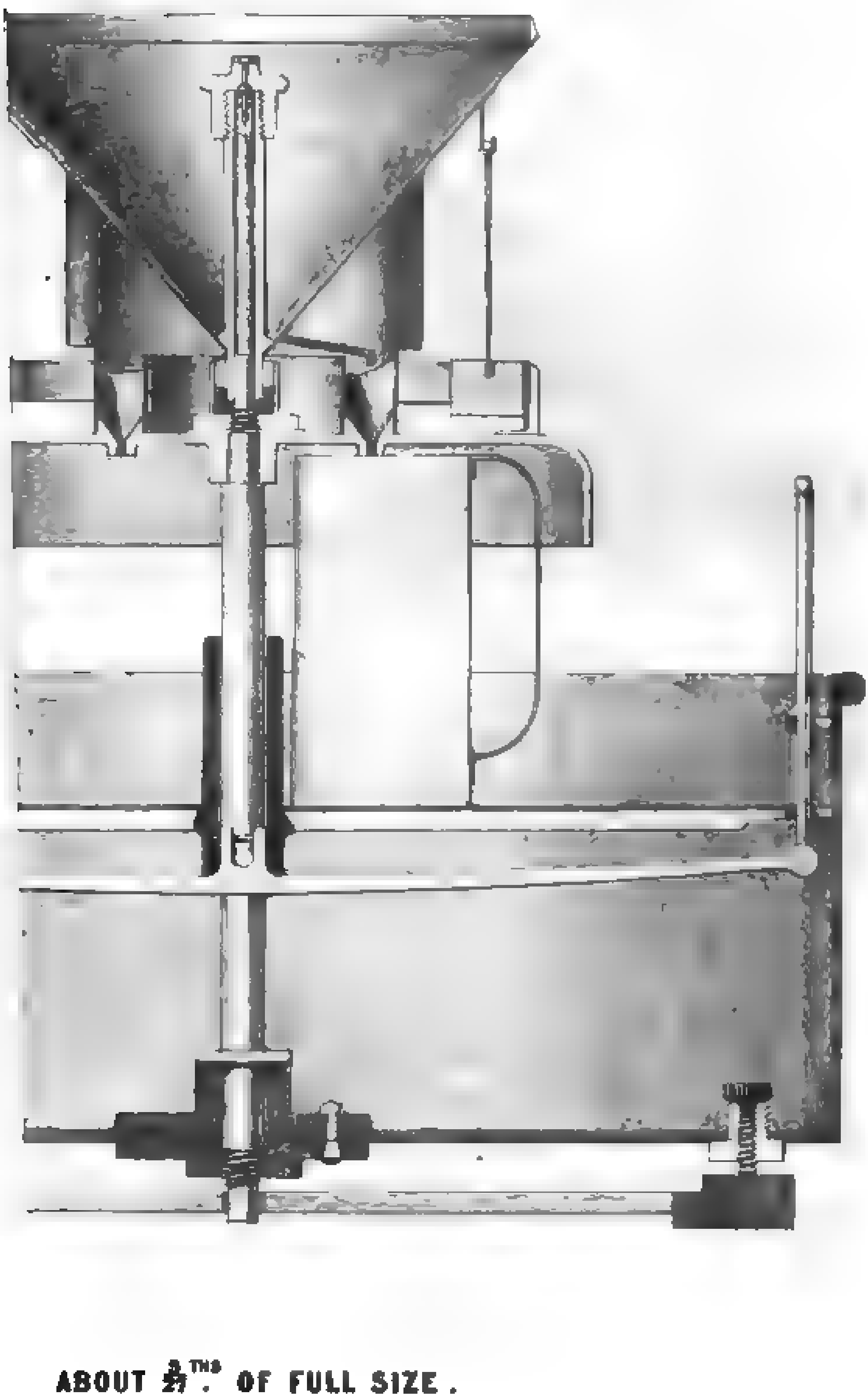
IV.—*On a Wind-direction Rain-gauge.* By Mr. James R. Napier, F.R.S.

Read before the Society, November 30, 1870.

About thirty years ago, the writer made a simple apparatus for discovering the amount of rain-fall, with the direction from which it came. It was rudely made, and ordinarily useful. It shewed that if a more delicate apparatus were wanted, it could be produced at little cost. Very recently this has been desired, and a gauge on the same principle erected at Shandon, on the Gareloch.

DIRECTION RAIN-GAUGE

t WEST SHANDON, GARELOCH.



ABOUT $\frac{8}{27}$THS. OF FULL SIZE.

In meteorological observations, the amount of rain-fall, and direction of the wind, with other information, is arrived at by means of expensive self-recording apparatus, not always trustworthy as to the wind's direction; and where private registers of rain-fall are kept, the direction of the wind during rain is not known with any certainty, except when raining at the time of making the observation.

The principle of the Shandon gauge consists essentially in supporting a vessel, like the first receiver of an ordinary gauge, on a pivot, so that it may be turned with the least wind, and having a spout attached to it, leading the rain into vessels in fixed directions surrounding the receiver, so that if it rains, for example, when the wind is between N.N.W. and N.N.E., the north vessel receives it, or when between N.N.E. and E.N.E., the north-east vessel receives it, &c.; for there are eight vessels which shew the amount of rain and direction of the wind at the time.

As it was essential that it should turn with the least wind, the windmill system recommended by the Royal Society, and adopted at Kew, Glasgow, and other observatories, in their anemometers for its steadiness, was not adopted here, but the ordinary wind-vane, and a freely-suspended balance-weight, to act by its centrifugal force on a fixed ring in controlling the angular motions; for it was found on more than one occasion that these windmills were too steady,—the Glasgow one at least remaining unmoved in a direction at right angles to wind blowing at the time at the rate of fully four miles an hour.

The gauge has been very carefully made and balanced, so that its centre of gravity lies in the axis, and a little below the pivot, and its centre of figure or projection, approximately at the same place, in the expectation that with these positions there would be the least friction, and therefore the greatest delicacy.

The writer was not aware, till he had nearly finished his apparatus, that a small gauge of about 5 inches diameter had been proved to be nearly as accurate as one of 5 or more feet, otherwise he would have made the Shandon one smaller. As it is, it has a square foot of area. The moving parts weigh about 13 lbs., and when fitted in a closed room, 20 grains acting on the circumference of a drum $8\frac{3}{8}$th inches diameter turned it; or, taking the ordinary formula for velocity and pressure, with the area of the vane and its moment, into account, a velocity of wind of about one mile an hour at right angles to the vane would move it. The instrument is portable, was designed to rest on or near the ground; but when so placed at Gareloch its indications were unreliable, owing to the interference of house,

street, &c. It now rests on the top of a retaining wall, at about 3 feet from the ground on one side, and 4 feet on the other, with the side of the house about 10 feet from it on one side, and the [illegible] about the same distance off it on the other. It is free to the wind for at least sixteen points. It moves in the direction of a suspended silk thread, with a wind all but imperceptible, and the direction of which cannot be inferred by the senses within four or five points. As far as it has been observed with wind at about twenty miles an hour, the angular motion is sensibly controlled by the suspended weight, but its amount has not been determined by direct experiment. The foundation or base-plate of the apparatus was made a tank, with the intention of containing water to diminish the heating and consequent evaporation in the receiving vessels, in each of which, for the same object, there was to have been a float, but neither has yet been carried out.

A temporary measuring vessel, which appears to answer as well as the usual graduated glass jars, may be described. It is a tinned iron cylinder, about $\frac{1}{10}$th of the diameter of the gauge, and about 10 inches long, or such length as to contain exactly $\frac{1}{10}$th inch of rain.

A piston or cylinder of wood, of a little less diameter than the cylinder, and of the same length, and divided into ten equal parts by grooves, completed the apparatus. Every fill of the vessel is of course $\frac{1}{10}$th of an inch. When partially filled, and the piston inserted, it falls rapidly till it touches the water, when its velocity is so greatly reduced that the position of the water is *felt*, and shewn by the length of wooden piston visible above the top of cylinder, to about the fifth of a division, or $\frac{1}{500}$th of an inch of rain.

Note received 10th February.

The following are the records of rain-fall at West Shandon, as shewn by the gauge there:—

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Total inches.
From 3d to 10th December,	·04	·04	·40	·05				·03	·56
From 10th to 17th December,	·05	·29	·78	·23			·02	·10	1·37
From 17th Dec. to 7th Jan.,	·39	·40	·60	·80	·56	·20	·22	·20	3·37
From 7th Jan. to 4th Feb.,	·14	·10	·54	·30	·55	·27	·09	·07	2·06

The figure in the accompanying print gives a section of the Shandon gauge.

V.—*On the Attractions and Repulsions due to Vibration, observed by Guthrie and Schellbach.* By PROFESSOR SIR WILLIAM THOMSON, LL.D., F.R.S.

Read before the Society, December 14, 1870.

PROFESSOR SIR WILLIAM THOMSON began by stating that some very interesting papers had recently appeared in the *Proceedings of the Royal Society* and the *Philosophical Magazine*, by Professor Guthrie, in which some very curious hydrokinetic phenomena were described. From hints and suggestions in his paper, it seems certain that Mr. Guthrie connected in his own mind these phenomena with possibilities of explaining some of the more recondite actions in nature; and he (Sir William Thomson) believed that what gave the great charm to these investigations for Mr. Guthrie himself, and no doubt also for many of those who heard his expositions and saw his experiments, was, that the results belong to a class of phenomena to which we may hopefully look for discovering the mechanism of magnetic force, and possibly also the mechanism by which the forces of electricity and of gravity are transmitted. The lecturer, however, did not lay any stress at present upon the possibility of applying these results directly to explain magnetism. He believed, on the contrary, that the true kinetic theory of magnetism (and the ultimate theory of magnetism is undoubtedly kinetic) involves quite a different class of motions from this, to which the beautiful phenomena discovered by Mr. Guthrie are due. He rather wished to point out the close connection that existed between the laws of some of these actions and the laws of magnetism, which, while involving some remarkable coincidences, involves certain contrasts decisive against any hypothesis, such as the ingenious one of Euler, explaining magnetism by fluid motion, directly comparable with that which forms the subject of the present communication. One of the most brilliant steps made in philosophical exposition of which any instance existed in the history of science, was that in which Faraday stated, in three or four words, intensely full of meaning, the law of the magnetic attraction or repulsion experienced by inductively magnetized bodies. He pointed out that a small globe or cube of soft iron tended in a certain direction when free to move in the magnetic field;

while small detached fragments of inductively magnetized substances, to which he gave the name of dia-magnetic, tended in the contrary direction; and that the precise specification of the direction in which the iron tended was from places of weaker to places of stronger force. By means of diagrams, the lecturer then shewed the action of magnets upon small pieces of soft iron in various positions, in the several cases in which the magnetic force is due to a bar magnet, a horse-shoe magnet, and two bar magnets placed side by side with their similar poles in the same direction. A diagrammatic illustration of "the lines of magnetic force," in the case of a bar magnet, was also given. In the case of the horse-shoe magnet, it was pointed out that the small globe of soft iron would have a position of stable equilibrium at the line joining the poles, if free to move in the horizontal line bisecting at right angles the line joining the poles; this stable position being the point of greatest force. The attraction experienced would be towards this point; so that if the globe were placed inside this point—that is to say, nearer the bend of the magnet—it would seem to be repelled on the whole by the mass of steel while moving towards the place of strongest force. In the case of two magnets placed side by side with their similar poles in the same direction, it was pointed out that, for each pair of similar poles, there is a zero, or place of no force, midway between the two bars, and nearly in the line joining the ends. A globe of soft iron movable midway between the two bars is repelled, as it were, from each of the points of zero force, and finds a position of maximum force, which is one of stable equilibrium, on either side of either of the zeros. Faraday's law shewed that the soft iron was attracted from places of weaker to places of stronger force, quite irrespectively of the directions of the lines of force. He thus summed up a great variety of very curious and puzzling phenomena in one sentence.

This expression is perfectly applicable to small bodies moving through a moving fluid; with the substitution of "stream lines," instead of Faraday's "lines of magnetic force," and "greater or smaller fluid velocity," instead of "stronger or weaker magnetic force."

Mathematicians were content to investigate the general expression of the resultant force experienced by a globe of soft iron in all such cases; but Faraday, without mathematics, divined the result of the mathematical investigation; and, what has proved of infinite value to the mathematicians themselves, he has given them an articulate language in which to express their results. Indeed, the whole

language of the magnetic field and "lines of force" is Faraday's. It must be said for the mathematicians that they greedily accepted it, and have ever since been most zealous in using it to the best advantage.

Suppose a tube sunk in a perfect fluid, and the fluid made by some means to enter the one end and flow out by the other, the particles of it would follow the lines of magnetic force. The magnetic field of force in the neighbourhood of a bar magnet corresponded exactly with the straight tube taking water in at one end and discharging it at the other. If two such tubes were presented with like ends to each other, they attracted, but with unlike ends, they repelled,—thus acting differently from two magnets placed in similar relative positions. But, except in being precisely opposite in direction, the resultant action between the supposed tubes and that between two bar magnets follows rigorously the same law, both as to magnitude and as to line of action. This conclusion, and some others, containing the explanation of most of the experiments now to be shewn to the Society, had been worked out mathematically by the lecturer, and communicated by him to the Royal Society of Edinburgh.*

It had been found by Faraday that the lines of magnetic force were diverted outwards from itself by a dia-magnetic body being placed in the field. If a body existed of completely dia-magnetic inductive capacity, the lines of magnetic force would pass altogether round it, and none of them through it. This is precisely the phenomenon, with reference to stream lines, which is met with in the hydro-kinetic analogue. Sir William then drew attention to some small egg shells which were suspended so as to move freely, each in a horizontal circle. By slightly waving the hand in front of the eggs they were attracted, and the same phenomenon was produced by holding in their neighbourhood a vibrating tuning-fork. This corresponded to the behaviour of a dia-magnetic in the magnetic field, only that the direction of the motion was opposite. By means of a very delicate anemometer it was shewn that the phenomena were altogether independent of currents of air. The lecturer shewed that in whatever position, with one exception, the fork was held, the attraction was produced. The magnetic analogue to this fork would be a non-magnetic frame substituted for the tuning-fork, and bearing two small magnets laid across the ends, with similar poles pointing towards each other. In this case there would be a zero point in the middle, between the near poles.

* *Proceedings*, Royal Society, Edinburgh, February, 1870.

The same is true of the fluid velocity in the case of the tuning-fork. It would repel the suspended eggs from the zero point; but the experiment was one of too great delicacy for a lecture-room. Some very interesting experiments upon flames had been made by Mr. Tatlock, his assistant, which the lecturer had much pleasure in shewing to the Society. A vibrating fork was supported horizontally, and the flame of a candle brought near the vibrating ends. All that part of the flame on a level with the fork was repelled, and bent down in the opposite direction, as if by a current of air. On the vibration being stopped, the flame at once assumed its upright form. A tall flame, obtained from ordinary coal gas, was next brought into proximity to the vibrating fork, when the middle part of the flame was drawn out towards the fork, the upper and lower parts being repelled. In concluding, Sir William Thomson remarked, that it would be very wrong if he were to say that these experiments on the hydro-kinetic analogue contained a direct opening up of the question of the mechanism of magnetic forces. They did not go any way towards explaining magnetic forces; but it was impossible to look upon them without feeling that they suggested the possibility of some very simple dynamical explanation.

The PRESIDENT, in proposing a vote of thanks to Sir William Thomson, said that Sir William had always kept them up to the latest results of the researches in which he was engaged; and he was sure they would join with him in the hope that some of the remaining experiments on this subject would be brought before them by Sir William later in the session.

VI.—*On the Question as between Sir Roderick I. Murchison and Professor James Nicol in regard to the Age of the Rocks of the Central Highlands.* By JAMES BRYCE, M.A., LL.D., F.G.S., President.

Read before the Society, January 11, 1871.

(The publication of this paper is postponed.)

VII.—*Observations of the Recent Eclipse of the Sun in Spain.* By ALEXANDER S. HERSCHEL, B.A., Professor of Natural Philosophy in the Andersonian University, Glasgow.

Read before the Society, January 25, 1871.

ALTHOUGH the nature of the red prominences seen round the sun's limb was most satisfactorily investigated in the solar eclipses of the years 1868 and 1869; and their connection with the sun, completely established by Mr. Warren Delarue's photographs of the eclipse in Spain in 1860, might be regarded as fairly proved by observations of those which occurred in 1851 and 1858, the corona remained a comparatively neglected phenomenon, until the contradictory observations to which it has given rise, especially in the two previous eclipses, determined observers to submit it to the test of a severe cross-examination in the total eclipse of the sun which occurred last month. The observing parties were directed for this purpose to make unassisted, as well as telescopic sketches of its appearance, and to examine its light with the polariscope and spectroscope, assigning a separate duty to each observer, and locating as many parties as their numbers in the expeditions would permit, at various points on the path of the moon's shadow, so that as different terrestrial conditions as possible might be allowed to have their full share in modifying the results. Photographic means were also successfully employed, by means of long exposures, to record the extent and outline of the corona. Although cirrhus clouds unfortunately veiled its features to a great extent, and dense clouds completely foiled the preparations of a few of the parties in Spain, the following short account of their observations will shew that the careful preparation and skilful subdivision of their operations was not entirely thrown away:—

Of the four expeditions sent by the British Government to observe the eclipse, the two first, embarked upon the "Urgent," were directed to Cadiz and Gibraltar, in Spain, and a third to Oran, on the coast of Algeria. A few observers who joined the parties to the former points took their passage to Spain in the P. & O. steamer "Pera," from Southampton. A rougher passage than that of this steamer to Alexandria, in which one of her engines gave way, had not, it was said by her officers, been encountered for thirteen years before.

Some members of the expedition to Gibraltar, on board of the "Urgent," were also induced by the stormy passage to end their journey at Cadiz. Mr. Perry's party at the latter place was accordingly somewhat increased; and Mr. Ladd, and Captain Maclear, R.N., afforded him their assistance.

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brightened, the lines between D and F diminished to half their length; and as the sun's light broke in, all disappeared, and were replaced by the ordinary solar spectrum. The two green lines which appeared on the following limb were near E, and the blue line was decidedly between F and G.

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As the solar crescent decreased, its cusps appeared to be alternately drawn out and blunted; Baily's beads were formed, and the corona burst forth more than twenty seconds before totality. The prominences were numerous, but none apparently very remarkable. Mr. Browne, who made these telescopic observations, regarded their colour as a bright yellowish-red tint. The corona he considers to have been perfectly free from striation, of distinct outline, and approximately quadrilateral, extending farthest in the direction of first contact. Its brightest part appeared to the naked eye to be scarcely more than one-tenth, fading rapidly when one-fifth, but being still clearly visible at seven-eighths of the sun's diameter from the moon's edge. Some unassisted observers saw two curved rays; but the general appearance was that of a diffuse light, interrupted in four places distinctly, and in a fifth faintly, by dark intervals. It was white, and was rendered faint by the clouds. Totality ended by the formation of Baily's beads, and the corona was visible to the naked eye for fifteen or sixteen seconds afterwards.

Near Xeres, five miles eastward from San Antonio, the observers, Messrs. Naftel, Abbay, and Penrose, of Mr. Perry's party, were stationed very near the post occupied by the American expedition under Professor Winlock. An eye-sketch of the corona, and of the general appearance of the scene during the eclipse, a copy of which is figured in the *Graphic* of January 21st, 1871, was here taken by Mr. Naftel; while Mr. Penrose sketched the corona as seen through a telescope. Mr. Abbay was provided with a two-prism spectroscope belonging to Professor Young. With this instrument he noted the bright lines C, D, F, and afterward F, and a line rather more bright than F, at some distance on the less refrangible side of B,* C,

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In meteorological observations, the amount of rain-fall, and direction of the wind, with other information, is arrived at by means of expensive self-recording apparatus, not always trustworthy as to the wind's direction; and where private registers of rain-fall are kept, the direction of the wind during rain is not known with any certainty, except when raining at the time of making the observation.

The principle of the Shandon gauge consists essentially in supporting a vessel, like the first receiver of an ordinary gauge, on a pivot, so that it may be turned with the least wind, and having a spout attached to it, leading the rain into vessels in fixed directions surrounding the receiver, so that if it rains, for example, when the wind is between N.N.W. and N.N.E., the north vessel receives it, or when between N.N.E. and E.N.E., the north-east vessel receives it, &c.; for there are eight vessels which shew the amount of rain and direction of the wind at the time.

As it was essential that it should turn with the least wind, the windmill system recommended by the Royal Society, and adopted at Kew, Glasgow, and other observatories, in their anemometers for its steadiness, was not adopted here, but the ordinary wind-vane, and a freely-suspended balance-weight, to act by its centrifugal force on a fixed ring in controlling the angular motions; for it was found on more than one occasion that these windmills were too steady,—the Glasgow one at least remaining unmoved in a direction at right angles to wind blowing at the time at the rate of fully four miles an hour.

The gauge has been very carefully made and balanced, so that its centre of gravity lies in the axis, and a little below the pivot, and its centre of figure or projection, approximately at the same place, in the expectation that with these positions there would be the least friction, and therefore the greatest delicacy.

The writer was not aware, till he had nearly finished his apparatus, that a small gauge of about 5 inches diameter had been proved to be nearly as accurate as one of 5 or more feet, otherwise he would have made the Shandon one smaller. As it is, it has a square foot of area. The moving parts weigh about 13 lbs., and when fitted in a closed room, 20 grains acting on the circumference of a drum $8\frac{3}{8}$th inches diameter turned it; or, taking the ordinary formula for velocity and pressure, with the area of the vane and its moment, into account, a velocity of wind of about one mile an hour at right angles to the vane would move it. The instrument is portable, was designed to rest on or near the ground; but when so placed at Gareloch its indications were unreliable, owing to the interference of house,

trees, &c. It now rests on the top of a retaining wall, at about 20 feet from the ground on one side, and 6 feet on the other, with the side of the house about 60 feet from it on one side, and the Gareloch about the same distance off it on the other. It is free to the wind for at least sixteen points. It moves in the direction of a suspended silk thread, with a wind all but imperceptible, and the direction of which cannot be inferred by the senses within four or five points. As far as it has been observed with wind at about twenty miles an hour, the angular motion is sensibly controlled by the suspended weight; but its amount has not been determined by direct experiment. The foundation or sole-plate of the apparatus was made a tub, with the intention of containing water, to diminish the heating and consequent evaporation in the receiving vessels, in each of which, for the same object, there was to have been a float, but neither has yet been carried out.

A temporary measuring vessel, which appears to answer as well as the usual graduated glass jars, may be described. It is a tinned iron cylinder, about $\frac{1}{10}$th of the diameter of the gauge, and about 10 inches long, or such length as to contain exactly $\frac{1}{10}$th inch of rain.

A piston or cylinder of wood, of a little less diameter than the cylinder, and of the same length, and divided into ten equal parts by grooves, completed the apparatus. Every fill of the vessel is of course $\frac{1}{10}$th of an inch. When partially filled, and the piston inserted, it falls rapidly till it touches the water, when its velocity is so greatly reduced that the position of the water is *felt*, and shewn by the length of wooden piston visible above the top of cylinder, to about the fifth of a division, or $\frac{1}{500}$th of an inch of rain.

Note received 10th February.

The following are the records of rain-fall at West Shandon, as shewn by the gauge there:—

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Total inches.
From 3d to 10th December,	·04	·04	·40	·05				·03	·56
From 10th to 17th December,	·05	·20	·78	·22			·02	·10	1·37
From 17th Dec. to 7th Jan.,	·39	·40	·60	·80	·56	·20	·22	·20	3·37
From 7th Jan. to 4th Feb.,	·14	·10	·54	·30	·55	·27	·09	·07	2·06

The figure in the accompanying print gives a section of the Shandon gauge.

V.—*On the Attractions and Repulsions due to Vibration, observed by Guthrie and Schellbach.* By PROFESSOR SIR WILLIAM THOMSON, LL.D., F.R.S.

Read before the Society, December 14, 1870.

PROFESSOR SIR WILLIAM THOMSON began by stating that some very interesting papers had recently appeared in the *Proceedings of the Royal Society* and the *Philosophical Magazine*, by Professor Guthrie, in which some very curious hydrokinetic phenomena were described. From hints and suggestions in his paper, it seems certain that Mr. Guthrie connected in his own mind these phenomena with possibilities of explaining some of the more recondite actions in nature; and he (Sir William Thomson) believed that what gave the great charm to these investigations for Mr. Guthrie himself, and no doubt also for many of those who heard his expositions and saw his experiments, was, that the results belong to a class of phenomena to which we may hopefully look for discovering the mechanism of magnetic force, and possibly also the mechanism by which the forces of electricity and of gravity are transmitted. The lecturer, however, did not lay any stress at present upon the possibility of applying these results directly to explain magnetism. He believed, on the contrary, that the true kinetic theory of magnetism (and the ultimate theory of magnetism is undoubtedly kinetic) involves quite a different class of motions from this, to which the beautiful phenomena discovered by Mr. Guthrie are due. He rather wished to point out the close connection that existed between the laws of some of these actions and the laws of magnetism, which, while involving some remarkable coincidences, involves certain contrasts decisive against any hypothesis, such as the ingenious one of Euler, explaining magnetism by fluid motion, directly comparable with that which forms the subject of the present communication. One of the most brilliant steps made in philosophical exposition of which any instance existed in the history of science, was that in which Faraday stated, in three or four words, intensely full of meaning, the law of the magnetic attraction or repulsion experienced by inductively magnetized bodies. He pointed out that a small globe or cube of soft iron tended in a certain direction when free to move in the magnetic field;

while small detached fragments of inductively magnetized substances, to which he gave the name of dia-magnetic, tended in the contrary direction; and that the precise specification of the direction in which the iron tended was from places of weaker to places of stronger force. By means of diagrams, the lecturer then shewed the action of magnets upon small pieces of soft iron in various positions, in the several cases in which the magnetic force is due to a bar magnet, a horse-shoe magnet, and two bar magnets placed side by side with their similar poles in the same direction. A diagrammatic illustration of "the lines of magnetic force," in the case of a bar magnet, was also given. In the case of the horse-shoe magnet, it was pointed out that the small globe of soft iron would have a position of stable equilibrium at the line joining the poles, if free to move in the horizontal line bisecting at right angles the line joining the poles; this stable position being the point of greatest force. The attraction experienced would be towards this point; so that if the globe were placed inside this point—that is to say, nearer the bend of the magnet—it would seem to be repelled on the whole by the mass of steel while moving towards the place of strongest force. In the case of two magnets placed side by side with their similar poles in the same direction, it was pointed out that, for each pair of similar poles, there is a zero, or place of no force, midway between the two bars, and nearly in the line joining the ends. A globe of soft iron movable midway between the two bars is repelled, as it were, from each of the points of zero force, and finds a position of maximum force, which is one of stable equilibrium, on either side of either of the zeros. Faraday's law shewed that the soft iron was attracted from places of weaker to places of stronger force, quite irrespectively of the directions of the lines of force. He thus summed up a great variety of very curious and puzzling phenomena in one sentence.

This expression is perfectly applicable to small bodies moving through a moving fluid; with the substitution of "stream lines," instead of Faraday's "lines of magnetic force," and "greater or smaller fluid velocity," instead of "stronger or weaker magnetic force."

Mathematicians were content to investigate the general expression of the resultant force experienced by a globe of soft iron in all such cases; but Faraday, without mathematics, divined the result of the mathematical investigation; and, what has proved of infinite value to the mathematicians themselves, he has given them an articulate language in which to express their results. Indeed, the whole

language of the magnetic field and "lines of force" is Faraday's. It must be said for the mathematicians that they greedily accepted it, and have ever since been most zealous in using it to the best advantage.

Suppose a tube sunk in a perfect fluid, and the fluid made by some means to enter the one end and flow out by the other, the particles of it would follow the lines of magnetic force. The magnetic field of force in the neighbourhood of a bar magnet corresponded exactly with the straight tube taking water in at one end and discharging it at the other. If two such tubes were presented with like ends to each other, they attracted, but with unlike ends, they repelled,—thus acting differently from two magnets placed in similar relative positions. But, except in being precisely opposite in direction, the resultant action between the supposed tubes and that between two bar magnets follows rigorously the same law, both as to magnitude and as to line of action. This conclusion, and some others, containing the explanation of most of the experiments now to be shewn to the Society, had been worked out mathematically by the lecturer, and communicated by him to the Royal Society of Edinburgh.*

It had been found by Faraday that the lines of magnetic force were diverted outwards from itself by a dia-magnetic body being placed in the field. If a body existed of completely dia-magnetic inductive capacity, the lines of magnetic force would pass altogether round it, and none of them through it. This is precisely the phenomenon, with reference to stream lines, which is met with in the hydro-kinetic analogue. Sir William then drew attention to some small egg shells which were suspended so as to move freely, each in a horizontal circle. By slightly waving the hand in front of the eggs they were attracted, and the same phenomenon was produced by holding in their neighbourhood a vibrating tuning-fork. This corresponded to the behaviour of a dia-magnetic in the magnetic field, only that the direction of the motion was opposite. By means of a very delicate anemometer it was shewn that the phenomena were altogether independent of currents of air. The lecturer shewed that in whatever position, with one exception, the fork was held, the attraction was produced. The magnetic analogue to this fork would be a non-magnetic frame substituted for the tuning-fork, and bearing two small magnets laid across the ends, with similar poles pointing towards each other. In this case there would be a zero point in the middle, between the near poles.

* *Proceedings*, Royal Society, Edinburgh, February, 1870.

The same is true of the fluid vibrating in the case of the tuning-fork. It would repel the suspended eggs from the zero point; but the experiment was one of too great delicacy for a lecture-room. Some very interesting experiments upon flames had been made by Mr. Taylor, his assistant, which the lecturer had much pleasure in shewing to the Society. A vibrating fork was supported horizontally, and the flame of a candle brought near the vibrating ends. All that part of the flame on a level with the fork was repelled, and bent down in the opposite direction, as if by a current of air. On the vibration being stopped, the flame at once assumed its upright form. A tall flame, obtained from ordinary coal gas, was next brought into proximity to the vibrating fork, when the middle part of the flame was drawn out towards the fork, the upper and lower parts being repelled. In concluding, Sir William Thomson remarked, that it would be very wrong if he were to say that these experiments on the hydro-kinetic analogue contained a direct opening up of the question of the mechanism of magnetic forces. They did not go any way towards explaining magnetic forces; but it was impossible to look upon them without feeling that they suggested the possibility of some very simple dynamical explanation.

The President, in proposing a vote of thanks to Sir William Thomson, said that Sir William had always kept them up to the latest results of the researches in which he was engaged; and he was sure they would join with him in the hope that some of the remaining experiments on this subject would be brought before them by Sir William later in the session.

VI.—*On the Question as between Sir Roderick I. Murchison and Professor James Nicol in regard to the Age of the Rocks of the Central Highlands.* By James Bryce, M.A., LL.D., F.G.S., President.

Read before the Society, January 11, 1871.

(The publication of this paper is postponed.)

VII.—*Observations of the Recent Eclipse of the Sun in Spain.* By Alexander S. Herschel, B.A., Professor of Natural Philosophy in the Andersonian University, Glasgow.

Read before the Society, January 25, 1871.

Although the nature of the red prominences seen round the sun's limb was most satisfactorily investigated in the solar eclipses of the years 1868 and 1869; and their connection with the sun, completely established by Mr. Warren Delarue's photographs of the eclipse in Spain in 1860, might be regarded as fairly proved by observations of those which occurred in 1851 and 1858, the corona remained a comparatively neglected phenomenon, until the contradictory observations to which it has given rise, especially in the two previous eclipses, determined observers to submit it to the test of a severe cross-examination in the total eclipse of the sun which occurred last month. The observing parties were directed for this purpose to make unassisted, as well as telescopic sketches of its appearance, and to examine its light with the polariscope and spectroscope, assigning a separate duty to each observer, and locating as many parties as their numbers in the expeditions would permit, at various points on the path of the moon's shadow, so that as different terrestrial conditions as possible might be allowed to have their full share in modifying the results. Photographic means were also successfully employed, by means of long exposures, to record the extent and outline of the corona. Although cirrhus clouds unfortunately veiled its features to a great extent, and dense clouds completely foiled the preparations of a few of the parties in Spain, the following short account of their observations will shew that the careful preparation and skilful subdivision of their operations was not entirely thrown away :—

Of the four expeditions sent by the British Government to observe the eclipse, the two first, embarked upon the "Urgent," were directed to Cadiz and Gibraltar, in Spain, and a third to Oran, on the coast of Algeria. A few observers who joined the parties to the former points took their passage to Spain in the P. & O. steamer "Pera," from Southampton. A rougher passage than that of this steamer to Alexandria, in which one of her engines gave way, had not, it was said by her officers, been encountered for thirteen years before.

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not noticed then. Although not noted in the memorandum, the observation appears to have been made at a point external to the prominences, and apparently on the corona.

Farther along the line of central shadow, about seventeen miles from San Antonio, a magnificent view of the eclipse was obtained near Arcos, and a sketch of it was made there by Mr. Warrington Smyth with a telescope of the same aperture as that used by Mr. Penrose. The observers, Mr. O. Airy, and Mr. Hammond (assisted by Lieut. Worgan and Mr. Atkinson), who joined Mr. Perry at San Antonio, contributed some general observations to this expedition, arriving from England at Gibraltar in the "Pera."

Lord Lindsay established his private photographic observatory in a convenient site, about five miles from San Antonio towards San Lucar, where a clear view of the sky enabled him to obtain seven excellent photographs of the total phase. With these he arrived in England in time to be present at the first re-assembly of the Royal Astronomical Society in London, after their adjournment, and the departure of the eclipse expeditions in the previous month.

In view of the possible event of cloudy weather, the members of the expedition who landed at Gibraltar, under Capt. Parsons, separated into two divisions, all except Capt. Parsons, Mr. Abbatt, and Mr. Talmage proceeding to Estepona, a village on the Mediterranean coast of Spain, about thirty miles from Gibraltar, and on the central path of the eclipse. The weather proved so capricious, that at Gibraltar Mr. Abbatt alone glimpsed the corona, and four high prominences, through a telescope, for about two seconds; while the micrometrical measurements of the position of Saturn, and of the possible refraction of its rays in passing through the corona, intended to be observed by Mr. Talmage, and of the polarization of the corona by Capt. Parsons, at a point about a quarter of a mile from Mr. Abbatt's station, were entirely prevented by clouds. Mr. Abbatt reports that there were more red prominences than the four just noticed, and that "in no part did the corona or the prominences extend more than an eighth, or at most a sixth part, of the moon's radius beyond the moon's limb." A drawing of the eclipse, exhibiting numerous prominences, and, apparently, *no corona*, carefully executed with a telescope by Corporal Munro, at the Signal station

(F), near the summit of a prominence, added to the green coronal line (near E) some distance on the less refrangible side of *b*. [A disposition of the spectroscope, by Professor Young, admitted light to the slit from every part of the eclipse at once, instead of, as usual, from a single point only of the corona, or of the prominences.]

at Gibraltar, appears in the *Graphic* of January 14th, 1871, together with a description of the scene from that lofty point of view, 1,268 feet above the sea. The corona is said to have been large and well-defined, and its outline, although confused by cirrhus clouds, was certainly attended by brilliant rays. Its light was pearly white, and a bright ruby tint was observed on all the prominences. While the dark shadow passed over the Rock, and veiled the grand panorama surrounding it in night, the lights on the African shore at Algeciras were distinctly seen, and very distinct clouds near the horizon, in the direction of the Atlas mountains, continued bright.* On board of H.M.S. "Trafalgar," alongside of the new Mole, drawings of the eclipse, of great interest, were made by the officers, three of which are reproduced in the *Illustrated London News* of January 14th. In that which exhibits the total phase the corona is represented as a nearly uniform "glory," or circular pencil of white rays round the moon, extending to about one of its diameters from its edge. The other two engravings shew, from the thin crescent of the sun before disappearance, projecting obliquely downwards, three bright and sharp rays; and at re-appearance a similar ray is seen projecting from the crescent near its lower cusp. The colour of these rays, which remained visible for half a minute, was bright red. By means of telegraphic time-signals to Professor Harkness at Syracuse, Professor Newcombe, of the U.S. expedition, observed the difference of longitude, and obtained the time of all the four contacts at Gibraltar successfully,—which observations will assist in ascertaining the correctness of Pierce's lunar tables. Several stars and planets were visible in the darkness; but the planet Saturn, in the corona, does not appear to have been seen by any of the observers, with the naked eye.

At Estepona the total phase was seen for about fifteen seconds; and Mr. Carpmael traced a line near one of the doubtful coronal ones. Mr. Anson obtained a short view of the corona, which would enable him to produce a fair representation of it from memory; and Mr. Lewis, who directed the party, found that its light was polarized. The preparations of the other observers at Estepona, including Mr. Buckingham's excellent arrangements for photographing the total phase, were unfortunately frustrated by clouds and rain.

Observations of the greatest interest among those obtained in

* At Seville, where the eclipse occurred during rain, and the total phase was lost to sight, the charcoal-burners' fires in the mountains, some five leagues distant [five Spanish leagues are about twenty-one English miles], were plainly visible. The correspondent of the *Graphic*, at Gibraltar, also saw the fires of the charcoal-burners in the cork woods behind Algeciras, and about St. Roque.

Spain were recorded by the American observers, during a few minutes of almost clear sky, with only a very slight haze, while the total phase lasted at Xeres. The party employed four equatorial telescopes of from 5 to 8 inches aperture, driven by clockwork, besides some smaller ones, with one of which several photographs of the total phase were taken by Mr. Willard, and his assistant. The positions of bright lines in the spectroscope were recorded by a registering apparatus devised by Professor Winlock, and fitted to each spectroscope. The perfection of the instruments may be inferred from the fact, that the first contact of the moon and sun was known by the moon's approach over the prominences in its path, before it reached the sun. At the first instant of totality, and for one or two seconds afterwards, the slit of the spectroscope being pointed to the moon's advancing limb, so as to coincide with the part of the sun's luminous border closest to its surface, Professor Young saw "the field of the instrument *filled with bright lines*. As far as could be judged, every non-atmospheric line of the visible spectrum shewed bright. From this observation (which was simultaneously confirmed by another observer of the same party), we seem to be justified in assuming the probable existence of an envelope surrounding the photosphere, and beneath the chromosphere, usually so called, whose thickness must be limited to two or three seconds of arc, and which gives a discontinuous spectrum, consisting of all, or nearly all, the ordinary lines, shewing them, that is to say, *bright* on a dark field."

The spectroscope of Professor Winlock, mounted on a telescope of 5½ inches aperture, shewed in the light of the corona a faint continuous spectrum, without dark lines; but among several bright lines which it contained, the most conspicuous line (1,474 Kirchhoff) was followed to a distance of at least 20′ from the moon's disc, all round the sun, and the positions of the other coronal lines were recorded by the registering apparatus. The extension of the same bright line from the moon's limb was estimated by Professor Young as not less than half the solar diameter, and all the spectroscopes shewed it as much the most conspicuous coronal line. Using three different kinds of polariscope, Professor Pickering detected radial polarization of the corona in every case, and observed that the light covering the moon's disc was polarized throughout in one plane. Observing the light of the corona with Savart's polariscope, Mr. Langley, whose interesting review of the observations made at Xeres is here briefly reproduced from *Nature* of January 21st, also found it to be radially polarized all round the sun. His impression of the corona, as seen through a 4½-inch telescope, with power 150, is that the part nearest

the sun was without striations, presenting a nearly uniform diffuse light, with the exception of a single "dark ray" in the field, which was noticed to be quite straight, and nearly radial. The outline of the corona was roughly quadrangular, with its longer diameter making as nearly as possible an angle of 45° with the vertical. The coronal structure is well shewn on a photograph taken during the totality, by Mr. Willard. In some well-marked features (an interesting drawing being made by a resident in the vicinity, Mr. Gordon) all agree, while in minor ones such differences exist that one might almost say that each saw a different corona. The red flames were beautiful objects; but they were not seen more distinctly, or more in detail during the eclipse, than they were viewed the day before through the spectroscope of Professor Young. Mr. Ross used a modification of Bunsen's photometer, and obtained several concordant measurements, shewing that the total illuminating power of the corona, and red flames, was equal to that of a standard candle at a distance of two feet.

At the meeting of the Royal Astronomical Society in London, on the 13th of January, the details of Lord Lindsay's expedition occupied the first place in the discussion, which resulted in the recognition of a new envelope, the "leucosphere," from the Greek word λευκος (white), encompassing the sun to a distance of 5′ or 6′ from its border, and apparently distinct from the outer radiating corona. Among the different eye-drawings exhibited of the eclipse, some were very grand, and not a few of them were remarkably dissimilar. Lieut. Brown, R.A., who accompanied Lord Lindsay's expedition, found, like Professor Winlock, a continuous spectrum of the corona, in which he failed, however, to detect the existence of bright lines at a point in the corona about 8′ from the moon's limb.

Next to the probability of the double character of the corona, the most important result of the observations of the eclipse, obtained in Spain, is undoubtedly the bright line spectrum of the corona seen by the United States observers. The most conspicuous line in its spectrum (Kirchhoff, 1,474) is the same as that detected (with two less certain ones) in the corona of the eclipse, in 1869, by Professor Young, which has now been traced to a distance of 15′ or 20′, corresponding to a height of 400,000 or 500,000 miles, all round the sun. On the other hand, in the bright stratum closest to the sun, to a distance of about 1,000 or 1,500 miles from its surface, Professor Young observed in the spectroscope a luminous vapour, in whose light every non-atmospheric dark line of the solar spectrum, as far as could be judged, shewed bright, or was reversed. Such, therefore, must be the depth

of the sea of flame whose absorbent vapours surrounding the sun give rise, according to the great discovery of Kirchhoff, to the well-known array of Frauenhofer's black lines in the solar spectrum. The ordinary height of the chromosphere, in which Mr. Lockyer has observed the bright lines of Magnesium, Sodium, Barium, Iron, &c., besides Hydrogen, at the base of the prominences, does not exceed 4,000 or 5,000 miles, which is also the utmost thickness that the photosphere is estimated by other astronomers to have, from the apparent depth of the cavity of the best observed solar spots. Compared with the whole gigantic extent of the sun's diameter, 850,000 miles, such shallow strata appear of almost liliputian thickness, to account for the marvellous complication of the light, and for the extraordinary changes which are constantly seen in active operation on the sun's surface. In the thin strata of the photosphere and chromosphere, the densest of the glowing vapours appear to be collected, while the extremely light incandescent hydrogen is thrown up, in the highest prominences, to elevations of 50,000 or 90,000 miles above the surface of the sun. Should, therefore, the bright-green coronal line, extending to a distance of more than 400,000 miles from the sun, indicate the existence of a hitherto unknown chemical element, its brilliancy at such a height would evidently distinguish it as the lightest, and most nearly ethereal of all known substances. A single bright-green line was observed, in 1867, by Professor Ångström in the spectrum of the zodiacal light, and of the Aurora. Should its peculiar brightness afford observers with the spectroscope a means of tracing the forms and the presence of those feeble luminaries by day, as well as in the absence of the sun's light, by a future ingenious application of the hitherto remarkably successful Janssen-Lockyer method; the possible identity of the luminous substance producing all these phenomena, and perhaps the light of some comets like the nucleus of Temple's comet (I, 1866), and of the streaks of the November meteors, will then be capable of exact verification, and perhaps of safe assertion. The coronal line, 1,474, Kirchhoff (wave length about 5,300), is, however, very far from the green line (wave length, 5,567) observed by Ångström in the spectrum of the zodiacal light, and of the Aurora; and it is marked as coinciding with the place of a bright line of iron in Kirchhoff's map of the solar spectrum. A question of important interest in the further discussion of the spectroscopic observations will be resolved when the positions of all the bright lines, hitherto considered to have been recorded in the spectrum of the corona, are compared with the known elementary spectra; and it will then be known

if any element existing on the earth, or, as appears very probable, from the conspicuous appearance of the green ray, an element hitherto unknown to chemists, is discovered in the coronal matter, as visible to us in the highly gaseous character of its spectrum, recorded by the skilful efforts of observers in the late eclipse.

VIII.—*The Eclipse Observations in Sicily.* By DR. T. E. THORPE, Professor of Chemistry in the Andersonian University, Glasgow.

Read before the Society, January 25, 1871.

PROFESSOR THORPE regretted his inability to present the scientific results of the expedition to the Society in a more complete form than had hitherto appeared. These results had not yet been forwarded to headquarters, and although he had been in correspondence with individual observers, he had not succeeded in obtaining anything beyond a general statement of their work. Of course, they would all see that it was hardly possible to expect men to communicate their results before they themselves had given them to the world. The expedition to which he had the honour to belong, was sent out to Italy under the charge of Mr. Lockyer. The original destination of the party was to Syracuse; but the unfortunate wreck of the "Psyche," near Catania, rendered it necessary for the main portion to remain at that place. In the hurry and excitement of landing from the wreck, many of the instruments were slightly damaged; but, thanks to the ready co-operation of the American astronomers, who were also stationed at Catania, the damage done was quickly repaired. Detachments from Mr. Lockyer's party were sent to Syracuse, Agosta, and up Mount Etna; the section to which he (Professor Thorpe) was attached remained at Catania. The observations of this party were unfortunately not very successful; during nearly the whole of the time of totality the sky was covered with dense clouds; the corona was visible only for about 2¼ seconds, and the amount seen was but small. The small portion visible appeared as a level patch of luminous haze—without streamers or corruscations. The party up Mount Etna (under charge of Professor Roscoe) was equally unsuccessful. Just at the moment of totality, a tremendous hailstorm broke over the party, and rendered observation completely useless. The most important observation of the party was made by Mr. Burton at Agosta. This gentleman

was furnished with a spectroscope of which he could have made better use had it been provided with the means of making proper measurements. He saw, however, the green line in the spectrum of the corona observed last year by the American observers; unfortunately he could not determine its position, but it was his distinct impression that it was more refrangible than the line marked E by Fraunhofer. This green line might denote iron or hydrogen; but if so, why did not the other and more characteristic iron or hydrogen lines come out? This was perhaps the cardinal point observed, and the capture of this single fact was alone worth the trouble and anxiety of the expedition. Now, if this green line is not iron or hydrogen, the question remains What is it? To this query not the least semblance of an answer could be given. The line does not correspond with any contained in the spectra of the elements hitherto examined. From its position in the gaseous envelope it is probably the lightest of all known substances—lighter even than hydrogen. It was generally believed that this line would be found to be identical with that observed in the spectra of the aurora and zodiacal light. The speaker regretted that he could not give any satisfactory account of the polariscope work done at Agosta. Mr. Brett, however, who was appointed to sketch the corona, made some important observations. At Syracuse, the members were more fortunate, particularly as regards photography; and Mr. Brothers managed to obtain as many as seven exposures during totality. Mr. Brothers also made a few notes on the positions of the prominences: these were found to be almost identical with those mapped by Mr. Seabroke, at Catania, shortly before the time of first contact. The speaker exhibited a diagram, copied from a map supplied by Mr. Seabroke, of the position and height of the prominences. At Carlentini, Professor Watson, the well-known Director of the Ann Arbor Observatory, Michigan, had a most enchanting view of the corona: during the entire time of totality it was perfectly unclouded, and he was therefore enabled to sketch its form and appearance with great precision. The speaker shewed a copy of Professor Watson's original drawing. One of the chief points connected with this corona was that it evidently consisted of two parts, one a solar appendage, the other of terrestrial origin. On comparing the drawings of the prominences and of the form of the corona, a remarkable coincidence was observable. There was evidently some connection between the irregularities in the circumference of the corona and the forms of the prominences. Wherever the outer line of the corona seemed to protrude, underneath would be found a prominence. The fact was the

more striking as the observations which had led to the discovery were made by two perfectly independent observers acting without the slightest collusion, at a distance of nearly twenty miles from each other. With respect to the green line before-mentioned, the speaker asserted that he was convinced that it would be seen shortly without the aid of an eclipse. Observers would attempt to do for the corona what they had already achieved in the case of the prominences, namely, to see it round the unobscured sun.

DISCUSSION ON THE TWO PRECEDING PAPERS.

PROFESSOR GRANT remarked that, in consequence of the little attention which had been devoted to the corona, as seen during former eclipses of the sun, the recorded observations and drawings of the phenomenon presented great discordances. Some drawings were made of the corona of the eclipse of 1842, and on that occasion it was remarked that towards the dark limb of the moon there presented itself a zone of compact light, surrounded by a definite outline. Beyond this was a zone of scattered light, and still farther out, bundles of rays, suggesting the idea of what the painters draw round the heads of saints. There were thus three parts:—the zone of compact light adjoining the dark body of the moon; another zone of more scattered light; and, still farther, beams of light extending to a distance of seven or eight minutes beyond the exterior margin of the corona proper.

The appearances which the corona presented in the drawings made of the eclipse of 1851 were much the same as those of 1842. In 1858, a total eclipse of the sun occurred in South America. In the drawings given by Mons. Liais, who observed the eclipse in Brazil, there were some peculiarities shewing the corona infinitely more contorted than in the diagrams now exhibited. The drawings by Mr. Hennessey of the eclipse of 1868, inserted in the *Proceedings of the Royal Society*, were more complicated in their details than even those shewn by Mons. Liais. There appeared everywhere a multiplication of curved lines shooting out beyond the corona and returning again into it by curvilinear courses. In the eclipse of 1860, which the speaker observed in Spain, there was one of the extending rays, or rather bundles of rays, which exhibited a decidedly curved form. The remark of Dr. Thorpe, on the connection between the red prominences and the white patches which interrupted the irregularity of the outline of the corona, seemed to him to be capable of throwing some light on the question under discussion.

Might not the violent commotion, of which those prominences appeared to be an indication, have the effect of ejecting volumes of hydrogen (for the prominences appeared to be composed mainly of this element) into the solar atmosphere, which would subsequently return to the photosphere under the influence of the sun's gravitation, the two forces in action causing the ejected matter to describe a curvilinear path in the solar atmosphere? At all events, the complex irregularities by which the structure of the corona was generally characterized, as indicated by the observations and drawings of different observers of total eclipses of the sun, constituted one of the most serious of the difficulties presented by the physical problem of those phenomena; and he considered that if the connection referred to by Dr. Thorpe as existing between the irregularities in the outline of the corona and the prominences was sufficiently established by the recent observations, it would be the most valuable acquisition which had yet accrued to science in connection with the vexed question of the *corona.*

The PRESIDENT considered it highly probable that the green line was given by some unknown substance contained in meteoric matter present in the corona, and also in the higher regions of the atmosphere, being derived from meteors bursting there, and illuminated when an aurora occurred.

In reply to a question by MR. DAY, in regard to the form of curve shewn in the corona, towards the base of the prominences, PROFESSOR GRANT explained that it appeared to be parabolic, and that the nearest approach to the curve was seen in Mr. Hennessey's drawing. If the ejecting force was in a direction normal to the moon's limb, there would, of course, be no sensible curvature; but if inclined to the moon's limb, there would be a deviation from a rectilinear course. Any one looking at Mr. Hennessey's drawing would see that the curvatures were very confused, and indicated the action of some force violently exerted; and could not fail to be struck with the extraordinary contortions in the structure of the corona. Nor did it seem to him possible to resist the conclusion that such a complex phenomenon was due to the action of some force violently exerted upwards in the sun's atmosphere, and acting in combination with the sun's gravitation.

PROFESSOR HERSCHEL said that he had frequently turned the spectroscope to the aurora, and always observed this green line. The difficulty was to determine its exact place. Dr. Thorpe had drawn attention to the correspondence between the two diagrams of the red prominences, and of the protuberances of the corona; and

in a recent discussion of this subject, at the meeting of the Royal Astronomical Society, Mr. Warren Delarue remarked that the correspondence was frequently wanting, and that it sometimes appeared to be reversed. This might refer to the outer corona, but it might also be a characteristic difference between the red-flames and the inner corona, or leucosphere. Professor Herschel said that Mr. Proctor inclined to the opinion that the light of the corona is, in some measure, due to the streams of meteoric and cometic matter, which, we have good reason to suppose, must be constantly passing very near the sun. The general results of the observations of the corona, in the late eclipse, appear not unlikely to afford further grounds of support, and would perhaps add increased probability to this theory.

PROFESSOR THORPE said, with respect to the want of a perfect accordance between the two diagrams which had been detected by one speaker, he would remind that gentleman that the prominences round the sun were continually changing in form and position; and it must not be forgotten that Mr. Seabroke's map was made nearly two hours before Professor Watson's drawing. There was no question, however, about their accordance in the main. Professor Grant's remark about the peculiar colour of the bulgings of the corona reminded him (Professor Thorpe) of what Mr. Watson had said in the course of conversation on this subject, viz., that it appeared as if the matter of the corona had been thrown up by some eruptive force from below, when it curved slowly downwards by the action of gravity. He would here remark that Professor Watson's observation of the secondary, or variable, corona had been made on several previous occasions. The speaker read a portion of a letter from Mr. Burton, from which it appeared that the fact was known so far back as 1706, having been observed by Louville in London.

IX.—*On Helmholtz's Analysis of the Vowel Sounds.* By A. S. HERSCHEL, B.A., F.R.A.S., Professor of Natural Philosophy in the Andersonian University, Glasgow.

Read before the Society, February 8, 1871.

PROFESSOR HERSCHEL said that the interest which had drawn him to this subject was what he had at first conceived to be a difference

of statement between Professor Tyndall and Professor Helmholtz. Professor Tyndall, in his fifth Lecture on Sound,* stated that "the vowel O is pronounced when the mouth is so far opened that the fundamental tone is accompanied by its strong higher octave. A very feeble accompaniment of the third and fourth tones is advantageous, but not necessary. The vowel A derives its character from the third tone, to strengthen which, by resonance, the orifice of the mouth must be wider, and the volume of air within it smaller, than in the last instance," &c.

At the close of a description of the origin and peculiar composition of the vowel sounds, as investigated by himself, in his well-known work *On the Perception of Musical Sounds*,† Professor Helmholtz writes:—"The clang of the vowel sounds differs accordingly in an essential manner from that of most other musical instruments, in the peculiarity that the intensity of the overtones of which they consist does not depend upon the numerical order, but upon the absolute pitch of those partial sounds. When, for example, I sing *Ah* on the note E (at the bottom of the treble stave), the note B (in the second space of the upper ledger), which is reinforced, is then the twelfth, or the second overtone of the fundamental note. And when I sing the same vowel on the note B (in the middle of the treble clef), it is the second tone in the series (the octave of the fundamental note), which then acquires especial force." The vowel A in the two latter cases would not be characterized by a reinforcement of the same overtone. He hoped to be able to point out that the descriptions of some of the vowel sounds contained in Professor Tyndall's work may be shewn to agree with the results of Professor Helmholtz's investigations, when the principal experiments upon which they repose are recapitulated, as they would have been much more perfectly rehearsed in an appendix, to which Professor Tyndall appears originally to have intended to direct his readers.

Professor Herschel then went on to shew, by means of a diagram, the various positions assumed by a stretched cord, when plucked and released, so as to produce a musical note. The note which the string produced in these circumstances was a very mixed one. He then shewed that the cord, when made to swing with a simple cycloidal—or isochronous—pendulum motion, produced a simple note, and that it might be made to vibrate in this

* *Sound: a Course of Eight Lectures*, &c., second edition, p. 200.

† *Die Lehre von den Tonempfindungen*, &c., by H. Helmholtz, Professor of Physiology at the University of Heidelberg, second edition (1865), p. 180.

manner in two, three, four, or more sections, producing corresponding (harmonic) notes. Another diagram shewed the positions assumed by the string when all these vibrations existed together. Helmholtz's great theory, on which is founded the mode of perception of musical sounds which is advocated in his work, is, that single nerves of the ear are only capable of distinguishing single pendulous vibrations, and that there are found to be some three thousand of these nerves, each capable of perceiving a certain period of vibration. If the ear were to hear the sound produced by the cord when moving, as shewn in the diagram of mixed vibrations, it would recognize the existence of all these sounds, but, from the effect of usual habit, would regard them together as forming one sound. In the case of a piano-forte wire, struck by a hammer, Helmholtz has shewn with what intensity each of these curves, partial notes, or overtones exist, when the key of a piano-forte wire is struck by a musician. The lecturer then, by vibrating a stretched cord and touching it with a camel-hair brush, shewed the existence, in its natural sound, of the various overtones. The harmonic overtones of a column of air in an open organ pipe were then produced by increasing the force with which the current of air was sent through it. By means of the syren, it was demonstrated that the column of air passing into it contains vibrations at all possible rates, or, at all events, all the harmonics of the fundamental note. It was also shewn that the air passing through the reeds in the chanter of a bagpipe has an infinite variety of vibrations, the particular undulations which are selected, and which compose the note heard, being those which correspond to the length of the column of air in the resounding pipe. Professor Helmholtz observed, among many similar examples of the effects of resonance of an inclosed cavity of air, that a hollow sphere, with a small opening in one side, produces a simple note, with hardly any overtones; and for the purposes of experiment, it affords the best means of strengthening and of rendering audible to the ear a simple note. A tuning-fork being struck with a stick, rings shrilly with its higher overtones, while its fundamental note is scarcely audible; but on its being placed opposite the open mouth of a glass globe, or of a box, whose size corresponds with the wave of sound produced by the fork, the vibrations of the fundamental note were so intensified as to be heard all over the lecture-room. The lecturer produced some glass globes of various sizes, with a small and short tube opening from the one side, adapted to fit into the ear, and a larger and much shorter tube, intended to communicate with the open air,

exactly opposite to it, which were glass copies of Helmholtz's resonators. By sounding pitchforks of varying depth of tone opposite the holes in the resonators, the particular resonator corresponding to any fork could at once be detected by the manner in which it intensified its vibrations. With the assistance of resonators of this remarkably convenient form, Professor Helmholtz has ascertained that loud strains of the human voice, in singing, present a series of higher overtones, up to the fifteenth and sixteenth, of extraordinary brilliancy and richness.

The lecturer then, by means of a drawing of the larynx, from the laryngoscope, shewing a view of the glottis in singing, explained the discoveries made by a German lady—Madame E. Seiler—on the motion of the various parts of the larynx in the production of the chest register, the falsetto voice, and the head register. By means of a vibrating free reed, placed in a tube through which a current of air was caused to pass, an imitation was given of the manner in which the tones of the human voice were first described as being produced by Kratzenstein, and were afterwards more perfectly imitated by Professor Willis. It was shewn that, by placing a tube as a resonator of variable length over the pipe containing the reed, the overtones could be intensified or shut off, and at the greatest limit of the length of the resounding tube, the fundamental note of the reed is greatly enriched. A tube of the proper length, shaped like a cone, was shewn to intensify all the overtones of a free reed, in the highest degree; and hence the shape of the mouths and tubes of horns, and of the speaking trumpet, is made conical. The action of the lips in sending a blast, without musical sound, through a trumpet, resembles the action of the glottis in the larynx in the whispered voice; the hollow in the mouth corresponding, in whispering the vowels, to the feebly, and yet quite distinctly reverberating interior of the trumpet.

The manner in which Professor Willis, about the year 1829, succeeded in imitating the vowel sounds most successfully, was by the use of a "free reed," or an elastic metallic tongue vibrating quite through an orifice. By placing a resonating pipe, capable of being shortened like a telescope tube, over a tube containing such a reed as that used by Professor Willis, it can be shewn that, when the tube is too long, the reed could not be made to "speak." Having here a reed which makes about 1,000 vibrations in a second, shortening the tube to about 2½ inches clear, a sound is first produced which all in this room will recognize as distinctly resembling the vowel sound A (*Ah*). Shortening the tube still further, or by open-

ing a hole in its side with the finger, the sound E is produced. By means of a deeper reed, the first sounds produced, when the tube was shortened to about 4 or 5 inches, Professor Willis found to resemble the sounds of the vowels Oo and O; when the tube was further shortened, the vowels *Ah* and E were produced on its attaining the same lengths as with the reed pipe, now shewn in this illustration. Professor Willis concluded from his experiments that free reeds of a sufficient depth of pitch, strengthened by particular lengths of pipe, produce very satisfactory imitations of the sounds of the principal vowels Oo, O, *Ah*, and finally *Ee*. The lecturer then stated the results of Helmholtz's analysis of vowel sounds, shewing the characteristic sound of each vowel to be one or more musical notes of absolutely fixed pitch, whose positions were shewn in a diagram of the ordinary stave in the treble clef.* Illustrations were given by means of the glass sphere resonators, shewing that the resonator corresponding to a particular note, when any vocal sound was made through it, tended to produce the particular vowel sound which Helmholtz had discovered to be characterized by especial intensity of that note.

The lecturer then said that an explanation is perhaps given by Helmholtz's discovery, that the mouth resounds certain fixed notes for particular vowels, of the obvious, but not otherwise very easily intelligible fact, that the vowels can not only be pronounced when speaking aloud, but also with equal distinctness in whispering, when air is simply urged through the glottis, like the wind over the tongue of a dumb reed, with an unperiodical flutter. The rates of vibration characteristic of the different vowels are made regular and audible, in this case, by the resonance of the oral cavity, shaped in the peculiar form required to strengthen the same notes, and to utter the same vowels as in speaking them aloud. An experiment was then shewn, which made visible to the eye the state of vibration of the air, caused by the different sounds of the human voice, the apparatus for which was designed and constructed by Professor Helmholtz, and Mr. Koenig of Paris.† The apparatus consisted of a gas-tube, terminating in a cap and jet, through which a stream of gas was forced, passing, in the cap, over a stretched membrane placed at the end of

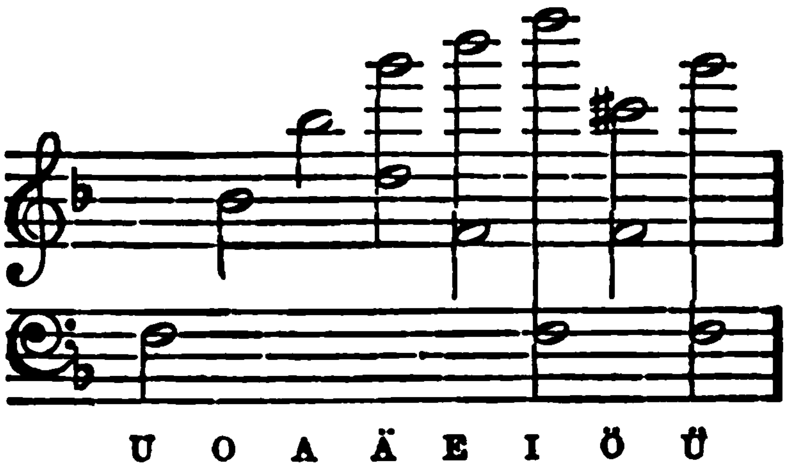
* By a mistake in drawing the diagram shewn, the stave having been inadvertently drawn with six, instead of with five lines, the recognition of the notes, although lettered, to prevent confusion, was rendered rather difficult and puzzling.

† By the kindness of Sir William Thomson, the lecturer was permitted to use and to exhibit the action of the instrument.

a short hearing-tube. The membrane and gas-jet are made to vibr by vocal sounds uttered in the mouth of the tube. Opposite the was a plane mirror, revolving about an axis, which is purposely somewhat obliquely to the perpendicular of the reflecting plane, that the mirror, when revolving rapidly, presents to the view image of the light carried so swiftly round in a circle that t impression produced upon the eye is that of an unbroken ring, long as the gas flame remains steady. When the voice causes t membrane to vibrate, the circle is broken up into rows of tee more or less in number, according to the higher or lower pitch of t voice. The use of a single mirror, set at an angle with a revolvi axis, permits the form of the teeth to be more minutely studied th the arrangement of four mirrors upon the sides of a revolving cul with which the agitations of the jet are, on the other hand, rath more plainly visible to a large audience. The study of the for of the flame-teeth, the lecturer said, was, however, surrounded l difficulties which had not yet permitted him to use them succes fully for the analysis of the vowel sounds. That the number of tl teeth is generally doubled, in passing, without change of pitch, fro Oo to O, and that the teeth are still more numerous with *Ah*, whi it remains the same in passing from Oo to Ee, are experimen which may be easily confirmed, when a note of a particular suitable pitch is chosen, and the sounds are well sustained. Fro another valuable series of experiments of Professor Helmholt which will now be described, the two notes B♭, in the bass cl appear very suitable, when sung with a loud voice, for the distin production, in their higher overtones, of the characteristic vow notes.

In order to produce the vowel sounds by a direct imitation of the characteristic notes, a set of eight tuning-forks, in a harmonic serie rising from the lowest B♭, last mentioned, to its third octave; an secondly, a similar series, rising from the upper B♭, in the bass cl to its third octave, were caused to vibrate by magnets, with rapidly intermittent electric current, before suitable resonators; tl loudness of their sound being controlled by small screens attach to keys, coming between the forks and the resonators, so as to sh out, or to admit the sound, and to allow it to be reinforced in va ous degrees. Although the characteristic vowel-notes are not exactly contained either in the first or in the second series of tl magnetic tuning-forks, yet, by sounding with especial force all tl overtones in one of the series which nearly coincide with the high ones, and with subdued strength, the bass note and other harm

nics of the series adjacent to the lower fixed note of any vowel intended to be imitated, a sound of mixed quality was produced, in which the particular vowel character could be distinctly recognized.

From the foregoing illustrations, the office of the mouth and throat, in fashioning the natural tones of the voice, admits of a satisfactory explanation. When, as in whispering, a strain of agitated air without sound enters their cavity from the glottis, one or more notes of fixed pitch (according to the particular vowels which the speaker intends to utter) become clearly discernible, from the effect of resonance of the air enclosed in their sonorous chamber. The characteristic notes (simple, and combined) of the different vowel sounds in the German language, analyzed by Professor Helmholtz, are shewn on the accompanying stave. When, on the other hand, the breath is urged through the vocal chords, strung to speak or to sing aloud a certain note, the same resonance of the oral chambers, as before, gives special emphasis to the partial tone of the notes which are nearest to the fixed note, or notes of the vowel chosen to be uttered by the voice; and in this manner the double resonance of the mouth and throat is most frequently employed to give a vowel character to the note; but, in the open vowels U, O, *Ah*, they form but one chamber, and their resonance is that of the simple notes represented in the above figured stave.

The passage in Professor Helmholtz's work, which was the immediate subject of these considerations, will now be fully understood. It states that if the vowel *Ah* is sung upon a note which is a twelfth below the fixed note that is characteristic of that vowel, the upper sound which is reinforced is the twelfth, or the second overtone of the fundamental note; but if, on the other hand, the vowel should be sung an octave below its characteristic note, the second partial tone, or first octave above the fundamental note, is the particular harmonic of the vocal sound which is reinforced. When, in order to test the accuracy of the above description, a series of harmonic sounds was formed upon the upper of the two B's in the bass stave as a fundamental note, it was found by Professor Helmholtz that a distinct U was obtained from the lowest of these sounds alone. A perfect O was produced when this note was rendered weaker, but accompanied strongly by its first higher octave, and with a slight

addition of the twelfth, or third tone of the series. The sound *Ah* was produced by the same notes, of which the second and third were moderately strong; and the fourth and fifth notes were strongly added, to complete the perfect vowel sound. In experiments with the same series, and with another series of tuning-forks of lower pitch, the strongest harmonics of the mixed sounds shewn to possess the vowel characters, were those adjacent to the distinctive vowel-notes. They coincide very closely in every important point with the description given of the vowel sounds by Professor Tyndall, quoted at the beginning of this paper; while, for more complete information on the subject, it appears to have been the author's intention to refer the reader to further experiments, and to recent discussions of this interesting question, by an appendix, in which some of the foregoing references and extracts from the valuable treatise of Professor Helmholtz would, perhaps, for the first time, have been presented to his readers in an English dress.

Professor Sir William Thomson said, that the improvement made in the apparatus of Helmholtz and Koenig, of substituting a single inclined mirror for a number of mirrors, was a very valuable one, since it would make it possible, if a steady speed of rotation were maintained, to count the vibrations in the different notes; and it would also serve other important purposes.

Mr. Colin Brown stated, as a peculiar fact, that the number of vibrations in the note F, in the bass stave (which Helmholtz had found to be the fundamental note corresponding with the vowel U), was a common divisor of the number of vibrations in all the other notes of the scale. Mr. Robert Brown, of Fairlie, had found that F was the fundamental tone in harmony, and it was the tone from which alone the scale could be derived. The sound of free air, also, as the sound of the wind when whistling freely, seemed to be characterized by the tone of F.

After some further remarks, suggesting practical applications of the gas-vibroscope to illustrate the elementary principles of harmony, by Mr. Miller and others, the subject dropped.

X.—*The Theory of the Death Rate, with Measurements of the Comparative Force of Mortality, in Glasgow and other Cities.* By MR. JAMES R. MACFADYEN, Fellow of the Faculty of Actuaries in Scotland.

Read before the Society, February 22, 1871.

IN commencing a paper devoted to an examination of the principles that should guide us in calculating the comparative force of mortality in various places, taking more especially for illustration the City of Glasgow, it seems almost necessary to apologize for once more bringing before this Society a subject so often previously discussed by it, and which, consequently, must have to it all the tedium of twice-told tales. We can only plead—unfortunately the plea is but too valid—the vital importance the death rate has to this community, and the hope we have, that, despite the various able addresses that have been delivered on this topic from this platform, the ground has not yet been wholly occupied, and that we may possibly to-night bring the matter before you from a somewhat different point of view.

In considering the question of a city's mortality, with the object of lessening the ravages of death in the midst of it, the natural order of setting about it seems to us to be as follows:—First, we have the collection of the facts by the Registrar. Next, the classification and arrangement of these facts by the statistician or actuary, who accordingly acts as death's historian, shews where he slays his thousands, where his tens of thousands, what age or sex feels his power most intensely, what weapon he uses here, and what there. The medical man next takes up the problem, and points out under what conditions the various prevailing diseases have their origin and virulence; and, lastly, the engineer, the architect, the sanitary reformer, have the duty of waging war on these conditions, and destroying them. Speaking broadly—for there is no fixed line of demarcation between any of these departments—this is the order in which the task must be undertaken; and the branch of it to-night, to which we shall more particularly direct our attention, is the second—the statistical—the one of all others that in the present state of the matter seems to us most requiring study.

Let us now proceed to the examination of the method by which

the force of mortality is measured. The probability of any given event is expressed by the fraction which has for numerator the number of chances of the event happening, and for denominator the number of chances both for and against it; or, in other words, the likelihood of any occurrence is the ratio of the number of chances favourable to it to that of the whole number, both favourable and unfavourable. Thus the chance to a man, say now aged thirty, of death in a year, is expressed by the fraction whose numerator is the number of deaths among men of his age in that year, and whose denominator is the number of men living at age thirty, his present age. If this denominator were a fixed quantity, subject only to diminution or increase at the close of each year, this fraction would also represent the death rate or force of mortality in that year among men aged thirty. But, of course, the denominator is not a constant but a variable quantity, changes in the numbers alive continually taking place; we therefore cannot express the death rate as the chance of death in a given year; for, in the fractions by which the two things are indicated, though the numerators are the same, yet the denominators are different,—that of the chance of death, being the number of men living aged thirty, that of the death rate, the number of men at risk through a whole year, aged thirty to thirty-one. If, then, we take the population as a whole of any city, and apply this principle, we shall have its death rate per 1,000 expressed by the formula—

$$1{,}000\ \frac{\text{Deaths in the city}}{\text{Total population at risk}}.$$

It is by this formula that the Registrar-General calculates the death rates of the various towns in those weekly Returns which are so familiar to us all from the newspapers. And it is principally on the evidence furnished by these statements that much that has been said on our local shortcomings in sanitary measures has been based.

To those who argue, from the comparative position of Glasgow in those Returns, that there must be a very large preventible mortality in it, we would merely wish to point out that this is not *necessarily* true. An examination of the formula will elucidate our meaning. It is obvious that the mortality varies with the age. If, then, one city has a larger proportion than another of lives that, in consequence of their ages, must have a high mortality, it may happen that the town which, by the preceding formula, has the larger death rate, is actually the better of the two as to health. As illustration: the death rate of infants is very high under any circumstances. Say, then, one borough has, in proportion to its population,

a much greater number of little children than another, and it must have a higher death rate, though possibly the healthier of the two. The preceding formula, then, and the ordinary manner in which the death rate is presented to us, assume that the numbers at risk at the various ages are in like proportions in each city. Again, females have, on the whole, a more favourable mortality than males; consequently, the towns in which the ratio they bear to the population is over the average will, in these statements, have an unfair advantage over their neighbours, which are not so fortunate in this respect.

So much for circumstances actually affecting the accuracy of these Returns as a measure of the death rate. Some sanitary reformers, however, go further, and seem to consider that if a city stands very badly in these statements, that there must be in it great neglect of sanitary requirements. This, however, is not *necessarily* true. It is only from comparison with other places that the position of any given borough, as to mortality, can be determined, and that comparison is worthless, unless the cities compared are in practically similar positions. But one town may have a greater proportion of its inhabitants engaged in occupations that from their very nature are unhealthy, than another has. In such a case the death rate must be higher in the former, though all matters pertaining to health be equally attended to. Again, since riches undoubtedly tend to longevity, cities in which wealth is more evenly diffused will, in these statements, have an advantage. The circumstances through which we might pursue the comparison are endless, and might almost seem to you like reducing the whole affair to an absurdity. Our sole object in pointing out this is to shew that too much may be made of these Returns. They shew a great deal, but not everything. We do not undervalue them; but neither do we consider that they can be taken as definitely settling the sanitary state of the principal towns. A bad position in them does not necessarily argue great neglect on the part of municipal authorities; and, above all, these statements do not leave matters in such a condition that remedial steps can at once be set about. The diagnosis of the disease is not sufficiently far advanced for that. These published death rates ought not then to be considered otherwise than as a rough measure of the force of mortality in the various cities.

Let us now proceed to examine the method we ought to adopt in order to free our Returns from the effects of varying proportions of age and sex. Carrying out the principles formerly laid down, we find the death rate per 1,000 in any population P is

$$\frac{1{,}000}{n}\left(\frac{\text{number dying between ages 0 and 1}}{\text{number at risk during first year of life}} + \frac{\text{number dying between ages 1 and 2}}{\text{number at risk during second year of life}} + \text{etc.}\right)$$

where n is the number of terms. This formula, applied separately for males and females, picks out from every city, not 1,000 persons in such proportions as to age and sex as the city contains, but 1,000 males or 1,000 females, an èqual number taken from each age in every place under review.

As on this formula, and on the one previously given, all our calculations of the death rate are founded, it may be well to throw them into an algebraíc form.

Let l_0, l_1, l_2, &c., be the numbers living at ages 0, 1, 2, &c., and $l_{\frac{1}{2}}$, $l_{1\frac{1}{2}}$, $l_{2\frac{1}{2}}$, &c., be the mean numbers living throughout the year, the deaths will consequently, between ages 0 and 1, be $(l_0 - l_1)$, between ages 1 and 2 $(l_1 - l_2)$, and so on. Let n, as before, be the total number of terms, or in other words, the age next birthday of the oldest living person. Then we have, by our last given formula, the death rate per 1,000:—

$$\frac{1{,}000}{n}\left(\frac{l_0 - l_1}{l_{\frac{1}{2}}} + \frac{l_1 - l_2}{l_{1\frac{1}{2}}} + \frac{l_2 - l_3}{l_{2\frac{1}{2}}} + \ldots \frac{l_{n-1}}{l_{n-\frac{1}{2}}}\right).$$

The force of mortality, when found in this way, we shall call the *analytical* death rate, as it takes into consideration the age and sex.

By the formula usually employed, and the one by which the ordinary calculations of the Registrar-General are made, we have, since in the 1,000 persons whose death rate is considered the number at each age is in the same proportion as in whole city, if number alive among the 1,000 of mean age $0 - 1 = {'l_{\frac{1}{2}}}$, the mean number of the 1,000 between ages 1 and 2, or ${'l_{1\frac{1}{2}}} = {'l_{\frac{1}{2}}}\frac{l_{1\frac{1}{2}}}{l_{\frac{1}{2}}}$. Similarly, ${'l_{2\frac{1}{2}}} = {'l_{\frac{1}{2}}}\frac{l_{2\frac{1}{2}}}{l_{\frac{1}{2}}}$, and so on. Therefore,

$${'l_{\frac{1}{2}}} + {'l_{\frac{1}{2}}}\frac{l_{1\frac{1}{2}}}{l_{\frac{1}{2}}} + {'l_{\frac{1}{2}}}\frac{l_{2\frac{1}{2}}}{l_{\frac{1}{2}}} + \ldots {'l_{\frac{1}{2}}}\frac{l_{n-\frac{1}{2}}}{l_{\frac{1}{2}}} = \left({'l_{\frac{1}{2}}} + {'l_{1\frac{1}{2}}} + \ldots {'l_{n-\frac{1}{2}}}\right) = 1{,}000 \;\therefore$$

${'l_{\frac{1}{2}}} = \dfrac{1{,}000\, l_{\frac{1}{2}}}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + l_{2\frac{1}{2}} + \ldots l_{n-\frac{1}{2}}}$, and ${'l_{1\frac{1}{2}}}$ therefore is $\dfrac{1{,}000\, l_{1\frac{1}{2}}}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \text{etc.}}$, and so on with other ages. But the rate of mortality of a life of mean age 0 is $\dfrac{l_0 - l_1}{l_{\frac{1}{2}}}$ $\therefore$ the rate of the ${'l_0}$ people alive among the 1,000, at age 0, is $\dfrac{1{,}000\, l_{\frac{1}{2}}}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots}\;\dfrac{l_0 - l_1}{l_{\frac{1}{2}}} = \dfrac{1{,}000\,(l_0 - l_1)}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots}$; and similarly the

number of deaths may be found for the other ages. Therefore, the total death rate of the 1,000 will be

$$\frac{1{,}000\,(l_0 - l_1)}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots.\, l_{n-\frac{1}{2}}} + \frac{1{,}000\,(l_1 - l_2)}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots.\, l_{n-\frac{1}{2}}} + \ldots. \frac{1{,}000\,(l_{n-1})}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots.\, l_{n-\frac{1}{2}}}$$

$$= \frac{1{,}000\, l_0}{l_{\frac{1}{2}} + l_{1\frac{1}{2}} + \ldots.\, l_{n-\frac{1}{2}}} = \text{death rate per 1,000 in city of stationary}$$

population, no account being taken of ages.

This method of calculation, which, as we have previously said, is simply the division of the deaths per 1,000 by the total risk population, we shall call the "aggregate" death rate, as it takes the people *en masse*, without regard to age. We are aware the words "aggregate death rate" are often used to denote the death rate of the whole, when those of various parts are given; but still it seems to us the best term for our purpose, and confusion can scarcely arise from employing it as is here done.

We have now got our formulæ theoretically, but we are not yet in a condition to apply them. The records of the Registrar will furnish the one element, the number of deaths in any given year; but where are we to get the corresponding risk population? It is neither the number at the beginning nor yet at the end of the year,—immigration and emigration, births and deaths, are continually affecting our calculations. To all great cities, the words of the "Earth Spirit" in *Faust* are applicable. Each is "an ocean of unending wave." In each "the swelling flood of life is flowing hither and thither." It is necessary, then, to make some allowance for these fluctuations. This is ordinarily done by assuming that every person dying, every one born, every immigrant and every emigrant, is subject to the risk for one-half the period of observation,—a correct assumption in the not improbable event of all entrances and departures being spread equally over the whole period under examination. Thus, if P = population at beginning of period, and 'P that at end of it, if B = births, D = deaths, I = immigrants, and E = emigrants, then the

$$\text{Risk population} = P + \frac{B + I - D - E}{2} = \frac{P + {}'P}{2},$$

since $'P = P + B + I - D - E$. That is, the risk population at a given age x, in any year, on the assumption of an equal distribution of entrances and departures, is the number equidistant between that at beginning and that at end of year—*i. e.*, is the number living in the middle of the year aged between x and $(x + 1)$, that is, $l_{x+\frac{1}{2}}$.

We have now arrived at the conclusion that, whether the aggregate or analytical death rate be wished, the number of lives

at risk taken is to be that at the middle of the year. The next question that meets us is, How is the population at this time to be ascertained? The Census is at present our only reliable basis. A few days ago the *Pall Mall Gazette*, in a leader, advised us to get rid of the trouble of Census-taking, and the asking of impertinent questions about people's ages, by the simple process of sending to Somerset House a record of the births and deaths throughout the country, it remaining with the officials there to make up the population estimates from them. This recommendation of the *Pall Mall's* is characteristically in unison with those made by "the mob of gentlemen who write with ease" on scientific subjects by the help of a quarter of an hour's consultation of a Cyclopædia, or similar authority. If the statists at Somerset House found all that was requisite for the taking of a Census in the birth and death Returns, they already have the materials for it. But, unfortunately, more is required; and even with the advantage of previous enumerations, the *Pall Mall Gazette's* recipe for a Census, though possibly available for the whole country, will fail for the various cities and districts in it, as the fluctuations of the population in them are great, and the defects of the English registration system are glaring. In this last point we are touching on a matter very often overlooked by statisticians in comparing the Returns furnished by England and Scotland. And yet the imperfections of the English Register are such as to put comparison, on various subjects, all but out of the question. The Scottish Registration Act compels Returns under penalties; the English Act is simply permissive,—and the permission is taken advantage of largely—not to comply, but to dispense with its provisions. To such an extent is this carried, that, in the Census Report of 1861, it is estimated that 36,000 births per annum escaped registration. We can arrive at some idea of the number of births not recorded from the excess of the population at the Census over that which it ought to be by the Returns; but the deaths not registered cannot be got at in this manner, and we have no reason to assume exactness in their record either,—a most serious matter when we come to compare the death rates of English and Scottish towns, and one that ought to be remembered in looking at the question. The Census, then, is an absolutely essential element in our calculations, and must, in some form or other, be the basis of our estimate of the population at risk. Even with it, however, unless we are to confine our investigations to the decennial periods of its being taken, we are obliged to consider what are the numbers existing in the various places at other dates. Various methods

have been adopted for this purpose. The Registrar-General for England, in calculating the population of the various boroughs, in order to ascertain their death rates, assumes that the numbers at risk will, from year to year, form a geometrical progression, the common ratio being that of the increase or decrease from 1851 to 1861. The Registrar-General for Scotland takes an arithmetical progression as his basis, and from the common difference arrived at by a consideration of the same Census Reports, interpolates the numbers for the various years since that date. Locally, we have a third method, as our respected City Chamberlain, Mr. Watson, gets at his numbers by taking the product of the inhabited houses, and the average number found to exist in a family by the last Census. Which mode is the most reliable? That is a question that seems to us can only be answered by a practical reference to the results of various Censuses, and must be relegated to the future. No doubt, a population having a natural growth only—by which we mean, one affected only by the excess of births over deaths—increases in geometrical progression; but in great cities, immigration and emigration destroy this uniformity. Mr. Watson, in his Report for 1869, brands the method of the Scottish Registrar as incorrect. We confess we are at a loss to see why. Not much can be said, *à priori*, either for or against any of these plans, we think; but we certainly do consider that the assuming the numbers from year to year as forming an equidifferent or an equirational series as likely to be correct as the method employed by Mr. Watson in his able Reports; and they are not, like it, liable to the possibility of a very slight difference in the one factor of the calculation deeply affecting the product, in consequence of being multiplied into the other large factor. However, whatever be the principle adopted, as they are all founded on the known Census Returns, the differences in the results are small; and if, in making our calculations, the same method be adopted in all cases, the possible inaccuracy will have practically no effect on the comparative position of the various places in our deductions. In our estimates we have followed the plan of the Scottish Registrar-General, and assumed that the numbers from year to year existing at every age in the various towns form an equidifferent series. This we have done solely for convenience sake, as by adopting it we have been enabled to press into our service some of the Scottish Registrar-General's estimates, and as, also, an arithmetical series is more easily handled than a geometrical one. The places to which we have applied it for the calculation of the death rates, both by the analytical and aggregate methods, are the cities of Glasgow and

Edinburgh in Scotland, and, in England, the Registration Districts of Liverpool and West Derby, Manchester and Chorlton, and Salford. The years taken into consideration are those from 1861 to 1867 inclusive, the latter year being the latest of which the detailed Reports have yet been published. The yearly deaths taken were the seventh part of the total number,—our results are thus the average of the seven years, and are consequently safer for generalization than those of any individual year—having a broader basis to rest on. It will be noticed, we say, that we have in England examined the Returns of the *Registration Districts* of Liverpool and West Derby, Manchester and Chorlton, and Salford, and not of the *Boroughs* of Liverpool, Manchester, and Salford. We have been driven to this course, because the Registrar-General for England, in his Reports, ignores boroughs altogether, and parcels the country into districts, which, though often called by the names of the cities in them, may be only parts of these cities, or still worse, either part or whole of the city, and something beyond it. The result of this arrangement is, that it is quite impossible for any one to estimate the proper death rate of the boroughs from these Returns. We shall illustrate the state of things by a fair sample of the difficulty we have had to encounter in the matter. To estimate the analytical death rate of males in Manchester, we required the numbers living at the various ages, and also the corresponding deaths at each age. The former we arrive at by calculations founded on the Census Returns for 1851 and 1861,—the latter ought to be furnished by the Registrar's Annual Reports. We turn to these Reports, and find in them the death tables required for a place called Manchester, but of which the population given as existing in 1861 will by no means agree with that of the city of Manchester according to the Census. A closer inspection of the Census Report shews us that the Borough of Manchester lies partly in the Registration District of Manchester, and partly in that of Chorlton, but that the Districts of Chorlton and Manchester together are more than the Borough of Manchester. In the Registrar's Reports, then, we find the deaths belonging to the Borough lurk *perdu* among those for these Districts; but as no means of separation are furnished, the exact death rate of the city of Manchester is quite unattainable by any one from these Returns. The same is true of Liverpool and various other towns. This state of things is all the more unsatisfactory, as the information requisite is actually in the hands of the authorities, though not published,—for there is a table in these Reports shewing the total deaths in those Boroughs, and the corresponding *aggregate* death rate.

Let us hope that since we have got this much, we may before long get the other also, and the material for a more correct analysis of the mortality be furnished us. In the meantime, however, observers like ourselves are obliged, for such places as Manchester and Liverpool, to take the death rate not merely of the urban populations, but of the suburban also.

With this explanation, we shall now proceed to consider the various death rates.

The accompanying Table shews that whether we take the aggregate or the analytical death rate, Liverpool is by much the most unhealthy of the towns under examination. That, according to the latter principle of measurement, next follows Glasgow, with Manchester not far behind it. Next Salford; and lastly, Edinburgh, close to Salford. As example of the possible changes of position that may be effected by the adoption of one or the other principle, it may be observed that while, by the aggregate death rate, males in Salford would have a lighter mortality than in Edinburgh, yet by the stricter analytical death rate the reverse is true. While, too, it cannot be said that there are great differences in the comparative results by the two methods, yet it appears that on the whole the aggregate principle of measurement favours both Manchester and Salford, but especially the latter, at the expense of Glasgow, Liverpool, and Edinburgh; and Manchester, Salford, and Glasgow, at the cost of Liverpool and Edinburgh. For the years under observation, then, the usually adopted method of calculating the death rate will give Manchester and Salford a somewhat lighter comparative mortality to that of Glasgow than they really possess, and Liverpool and Edinburgh a somewhat heavier, though the difference in any case is not great. It will be noticed that it is the excessive mortality among little children that gives Glasgow the unenviable position it holds of second in the death rate; as, for males over five years of age, it is a healthier place of residence, not merely than Liverpool, but also than Manchester or Edinburgh, and is nearly as eligible as Salford. While for females, over infancy, the only alteration in this order is, that it falls also below Edinburgh, though still superior to Manchester. Edinburgh seems to have by far the lowest mortality among children, and is consequently able, on the whole, despite the great mortality amongst those over five years of age, to take the lowest position of the towns under observation, though certainly not so low as might be supposed to be warranted by its comparatively small population. There are various points of interest in the

death rates at the various ages which, did time permit, it might be profitable to discuss, but which we must not now enter on.

In examining this Table, it ought to be remembered that the English Returns include suburban populations, which may be supposed to have a lighter mortality than the Boroughs proper, and consequently in our calculations the mortality of the cities will be somewhat under-estimated. The same effect will follow from the deaths that escape registration, as the corresponding births do not act as a balance, the risk population being calculated from the Census, and is thus not affected by the state of the Register. On the other hand, it should be mentioned (though it will have but a small effect on the death rate), that for the English districts, to save time and trouble, we have not corrected the numbers living from the 8th April to the middle of the year. As to the effect these points will have on the mortality force measurements of the English boroughs, it is impossible exactly to say. However, we cannot be far from the mark in stating that it will probably bring up the rate of Manchester to that of Glasgow, and leave Liverpool still worse than at present. The result of our inquiry, then, is, that on the whole, in the death rate, Glasgow and Manchester occupy the middle place between Liverpool on the one hand, and Salford and Edinburgh on the other; but that, except for infants, Glasgow is as healthy as any of these other towns. Among little children there, the mortality, however, is so great, that Salford and Edinburgh have (taking all ages) a decided advantage over it.

Having settled the place of Glasgow in reference to these Boroughs, we shall (as it is of more local importance to us) for the remainder of our paper, confine our attention to the Glasgow death rate alone, with special reference to that prevailing in the various Registration Districts of the city. As in the case of the English Boroughs, we have not here thought it necessary to bring down our population numbers to the middle of each year, and, for convenience sake, have employed simply the aggregate mortality of *persons*. The results of our examination will be seen in the following Table, and in the chart formed from it, on which the mortality curves of the various districts, and also of the city at large, for the nine years from 1861 to 1869, are described. We have taken, in each case, for our abscissa one year's time. Had we been in a position to undertake the very laborious calculations requisite, the curves would have been still more striking, if for abscissæ we had employed the consecutive weeks or months of the period, as we would thereby have been enabled to shew the changes in the

ordinates, not merely from year to year, but also within each year. However, the results as they stand seem to us startling enough to justify us in laying them before you.

The gap between the Blythswood, and not merely the High and Central, where the death rate is simply appalling, but every other District, is very great. In fact, the Blythswood section seems to have a mortality little if any removed from the healthy country provinces. The nine years' average positions of the Districts are as shewn in following Table.

As we thought it might be of some interest to try to trace any connection that might exist between the illegitimate birth rate and the death rate, we calculated the position of the various Districts in this respect also, though only for the seven years to 1867; but on the whole, though running similarly in some of the worst districts, there does not seem to be so close a resemblance as to warrant building on it. In thinking such a connection might exist, we were not guided by the opinion that the deaths among illegitimate children are more numerous than among legitimate. For, though this is undoubtedly true, we did not consider it at all adequate to account for the differences in the Districts, but we thought the relation possible, because where the vice and ignorance exist that favour illegitimacy, they would also favour the progress of death and disease. However, the preceding Tables, and especially the position of the Blythswood District, in the two respects, shew conclusively that the proportion of illegitimate births, though probably having an intimate connection with the death rate, has other causes affecting it which have no concern with the force of mortality.

Returning to our chart of the local death rates, we find the most extraordinary abruptness and waywardness in our curves,—a waywardness, be it observed, the more marked the more intense the force of mortality, till it finds its culmination in such Andes Peaks of death as the High District presents,—where, in two years, we pass from a death rate of forty-nine to one of thirty-nine, rising, however, almost immediately to forty-seven. These abrupt transitions (which shew clearly that the circumstances swelling our mortality bills are inconstant in their action, and therefore probably remediable), are, as we have said, generally less marked in our more healthy districts, till in the Blythswood division the form of the curve approximates to that of the city at large. Local influences, then, in this District have little effect on the death rate. Zymotic diseases, which are undoubtedly the chief agents of the extraordinary aberrations of the curves in the worst quarters, do not effect a hold in this favoured

AGGREGATE DEATH RATE OF PERSONS—GLASGOW DISTRICTS—AVERAGED FROM 1861 TO 1869 INCLUSIVE, AND PROPORTION OF ILLEGITIMATE BIRTHS TO TOTAL BIRTHS—GLASGOW DISTRICTS—1861 TO 1867 INCLUSIVE.*

	Districts arranged according to Intensity of Mortality.	Average Deaths / Risk Population	Average Deaths per 1,000.	Total Illegitimate Births / Total Births	Proportion per 1,000 of Illegitimate Births.	Districts arranged according to Intensity of Mortality.	
	Whole of Glasgow,	$\frac{13144}{422065}$	31·142	$\frac{11532}{121935}$	94·58	Whole of Glasgow.	
1.	High,	$\frac{2195}{50565}$	43·409	$\frac{1347}{15002}$	89·79	High,	1.
2.	Central,	$\frac{2087}{52241}$	39·949	$\frac{3154}{16741}$	188·40	Central,	2.
3.	Clyde,	$\frac{935}{28845}$	32·415	$\frac{1047}{7777}$	134·63	Clyde,	3.
4.	Calton,	$\frac{1147}{37951}$	30·223	$\frac{895}{10826}$	82·67	Calton,	4.
5.	Bridgeton,	$\frac{1435}{48325}$	29·695	$\frac{1189}{14136}$	84·11	Bridgeton,	5.
6.	Hutchesontown,	$\frac{1388}{47833}$	29·018	$\frac{1067}{14497}$	73·60	Hutchesontown,	6.
7.	Tradeston,	$\frac{1209}{43174}$	28·003	$\frac{764}{11893}$	64·24	Tradeston,	7.
8.	Milton,	$\frac{994}{36208}$	27·453	$\frac{805}{11410}$	70·55	Milton,	8.
9.	Anderston,	$\frac{1170}{45309}$	25·823	$\frac{808}{13552}$	59·62	Anderston,	9.
10.	Blythswood,	$\frac{584}{31614}$	18·473	$\frac{456}{6091}$	74·86	Blythswood,	10.

* The Risk Population is not corrected up till middle of year.

section as they do in the Clyde, Central, and High Districts. This may arise from the superior vitality of this the wealthiest District, or from the fact that, when contagious diseases appear, the isolation of the patients is more complete (an advantage, by the way, which should, from the different manner of building, render the death curves of English cities more uniform), or it may arise from a combination of these circumstances. Whatever be the cause, it seems to us a most suggestive fact, that the angularity increases with the death rate, and, we think, it is a most hopeful one for sanitary reformers. In considering the curves formed by the Central and High Districts, it ought to be remembered that the Infirmary and other public institutions are contained in them, and that their death rates are swelled by a mortality drawn to a certain extent from the city at large. However, making all allowances for this, their bad pre-eminence will still remain, and they still will be far ahead of the other Districts.

It will be observed in the chart that the curves do not in any of the Districts take a precisely similar course. They all bend upwards unfortunately, but they cross and recross each other,—one District shewing a temporary improvement, while another is getting worse. This is a very curious circumstance, and seems to indicate that local as well as general causes, such as temperature, have a large effect on the death rate. It would be not merely an interesting but a most useful study to take up the various Districts for the period under observation, examining into the state of trade and the industries in each of them, the diseases prevalent, and any local circumstances that may be thought to have a bearing on the question, and attempting to trace any possible connection between these matters and our curves. No doubt the general causes would to a certain extent mask the local, but still we think the labour would be amply rewarded. However, that is a task we cannot now undertake; and we merely throw out the suggestion for the consideration of some future student of our local statistics. There is, however, one great difficulty to be encountered. The Glasgow Registration Districts are far too large for any close analysis in this way. Each of them is a city in itself. We believe much more useful data for local sanitary purposes would follow were a minute subdivision of our Registration Districts made, and the death rate and peculiar circumstances of each subdivision examined. This we consider much the best method of arriving at practical results, and will help to dissipate the uncertainty at present experienced as to the effect of any experiment in the way of improvement. If we desire to estimate

the full weight and value of the Act that is making such changes in our overcrowded districts, it is in this way that we can best attain the gratification of our wishes. If the division be as minute as it ought to be, we have the means of ascertaining, not merely whether the local death rates in the vicinity of clearances have been lessened, but also whether, as has been asserted, there has been caused by these openings up,—such huddling together elsewhere as to create a mortality counterbalancing the good effected. In fact, what on the Continent is called a cadaster, is a thing most imperatively called for,—a minute subdivision of the city—the population to each part—their occupations, ages, birth and death rates, and all those particulars that students of the public health so much desiderate, but which they so very seldom obtain. Having this, we would be in possession of a gauge of the value of our remedial measures. Without it, sanitary reformers are in the position of physicians with patients whose diseases they cannot fathom, and on whom the effect produced by their prescriptions they are not allowed to see. With this, the pestilence would no longer walk in darkness, and some vantage ground would be gained in the battle with death. Without it, we strike at random, missing, perhaps, as often as we hit.

We have alluded to the general tendency upwards in the years under observation of the death curve. This is true of all the districts, and is also the case with Scotland at large. We are passing through a period of great intensity of mortality. The death curve seems not merely to have maxima and minima points from year to year, but over a series of years there will be a general tendency upwards, and then a similar one downwards. A wave of death has in this way swept over the country. We may venture to hope, perhaps, that we are now entering its hollow, and that 1869 was its crest. Whether this be the case or no, can only be determined by the experience of the future. That experience should be employed, not merely as the lantern in the stern of the ship, throwing a narrow track of fire on the billows already past, but rather as the beacon-light warning from dangers yet to come. Our present system of registration does little more for us than the former. Such subdivision as, following the lead of abler statists, we here advocate, would tend towards securing for us the latter benefit. In time we doubt not that, profiting by the example of other countries, a more thorough system of registration will be established, and the advantages flowing from the study of statistics will be better understood and appreciated. Science in this direction is yet

M 1861 TO 1867 INCL

HESTER AND CHORLT

...ate ...0.	City of Glasgow.		R...
	Deaths / Risk Population	Death Rate per 1,000.	
)	$\frac{1574}{7226}$	217·82	
l	$\frac{859}{5898}$	145·64	
1	$\frac{392}{5691}$	68·88	
)	$\frac{244}{5324}$	45·83	
)	$\frac{159}{5142}$	30·92	
3	$\frac{351}{22362}$	15·70	
3	$\frac{151}{19578}$	7·71	
2	$\frac{206}{20633}$	9·98	
2	$\frac{239}{21152}$	11·30	
0	$\frac{427}{31916}$	13·38.	
7	$\frac{453}{22927}$	19·76	
1	$\frac{472}{15504}$	30·44	
5	$\frac{400}{8335}$	47·99	
3	$\frac{454}{3824}$	118·72	
3	$\frac{6381}{195512}$	32·64	
7	$\frac{3228}{29281}$	110·24	
3	$\frac{3153}{166231}$	18·97	
8		56·01	
3		101·82	
2		30·55	

* The Risk Popula...

in its infancy. The things it has been doing are but earnest of what it yet shall do. And though it be not reserved to human effort to conquer death or stay disease, and though the "people must still perish for lack of knowledge," yet in this branch of science we believe that man has the means of lessening the ravages of the destroyer, of rendering more nearly true words of the Latin poet—at present only true in a most limited sense—that hovel and palace hear death's knock equally.

BAILIE MORRISON said there was one very practical suggestion made in the paper—viz., the division of the city into small areas, for the purpose of ascertaining the death rate. Pondering over the question, without having the least idea that Mr. Macfadyen was going to suggest that plan, he had proposed in the Health Committee that the whole city should be divided into small areas, to find out whether in any particular part, and in what part, the excessive mortality arose. There were many things that removed from his mind the alarm in regard to the great mortality in Glasgow. One of these was the greater inaccuracy of registration in the towns in England as compared with Glasgow. There was one circumstance, however, to which, above all others, he attributed the higher death rate in Glasgow, and that was, that Glasgow had in recent years prospered above every other city in the kingdom. It was only 300 years since we stood ninth in Scotland in population; now we stood third in importance in the United Kingdom. The reason for this was perfectly obvious, and had a great deal to do with our high mortality. Situated as we were in the centre of a populous mining district, we had a very large industry which attracted to the city an enormous floating mass of what we might call low-class population. This was perhaps more peculiar to Glasgow than to Liverpool or Manchester. In various manufactories in Glasgow, there were large numbers of men brought from the country with little or no idea of domestic comfort, who had been accustomed to share their cabin with the poultry and other animals, and to pay very little attention to sanitary matters. These habits could be indulged in with perfect impunity in their native glens, where they had the pure air of heaven to protect them from the results. But the importation of these habits into Glasgow produced consequences which greatly increased the death rate. The great mortality in the central district was caused to some extent by overcrowding of houses, by their being built too closely together, as well as by the individual houses being overcrowded with people. In the course of some years the former

cause would be removed, and he hoped that there would be an improvement. In the northern district the overcrowding in the Havannah, and the state of the Molendinar, had something to do with the mortality.

Mr. Mayer thought there was an important thing in connection with the death rate of Liverpool which had not been taken notice of. The years taken in included the two years during which there was an enormous death rate from cholera. In connection with the low infantile death rate in Edinburgh of children under five years of age, it should be remembered that there was a very large population of retired people there, whose existence exercised a considerable influence on the returns.

Mr. Melvin drew attention to the fact, that in England the registration of illegitimate births was not compulsory, as it was in this country, and therefore it was very unfair to compare the one country with the other in this respect.

Bailie Morrison said that those parties who were interested in the sanitary condition of the city would be glad to hear that the district in the northern portion of the city was all being rapidly acquired with the purpose of remodelling it so as to improve its sanitary condition. The little lanes running down from the Molendinar were all to be remodelled, and the burn itself covered up. He thought this would remove the blight from that part of the city. In order fairly to estimate the population at present in the districts to be operated on, it was intended to divide them into blocks, and on a map to label each block with the number it contained, and thus shew at one view the density of the population.

Mr. W. R. W. Smith referred to a speech, made about two years ago at the Police Board, by the late Dean of Guild, Mr. M'Ewan, and to certain statistics in that speech, as shewing very high death rates in certain districts as arranged by Dr. Gardiner; and said that one of the districts in which the highest mortality occurred was that through which the burn ran which carried off the refuse from M'Farlane's distillery. Another district of the same character was that through which the pot ale from Messrs. Bulloch, Lade, & Co.'s was carried off. He found that there was 500,000 gallons of this passed down per week, containing 50 tons of dry material, all of which ran into the Kelvin. It was a very curious thing that in the very district through which this sewer passed there should be such a high death rate. Of course, it was coupled with other matters that came down; but it was curious that there was the high death rate in the

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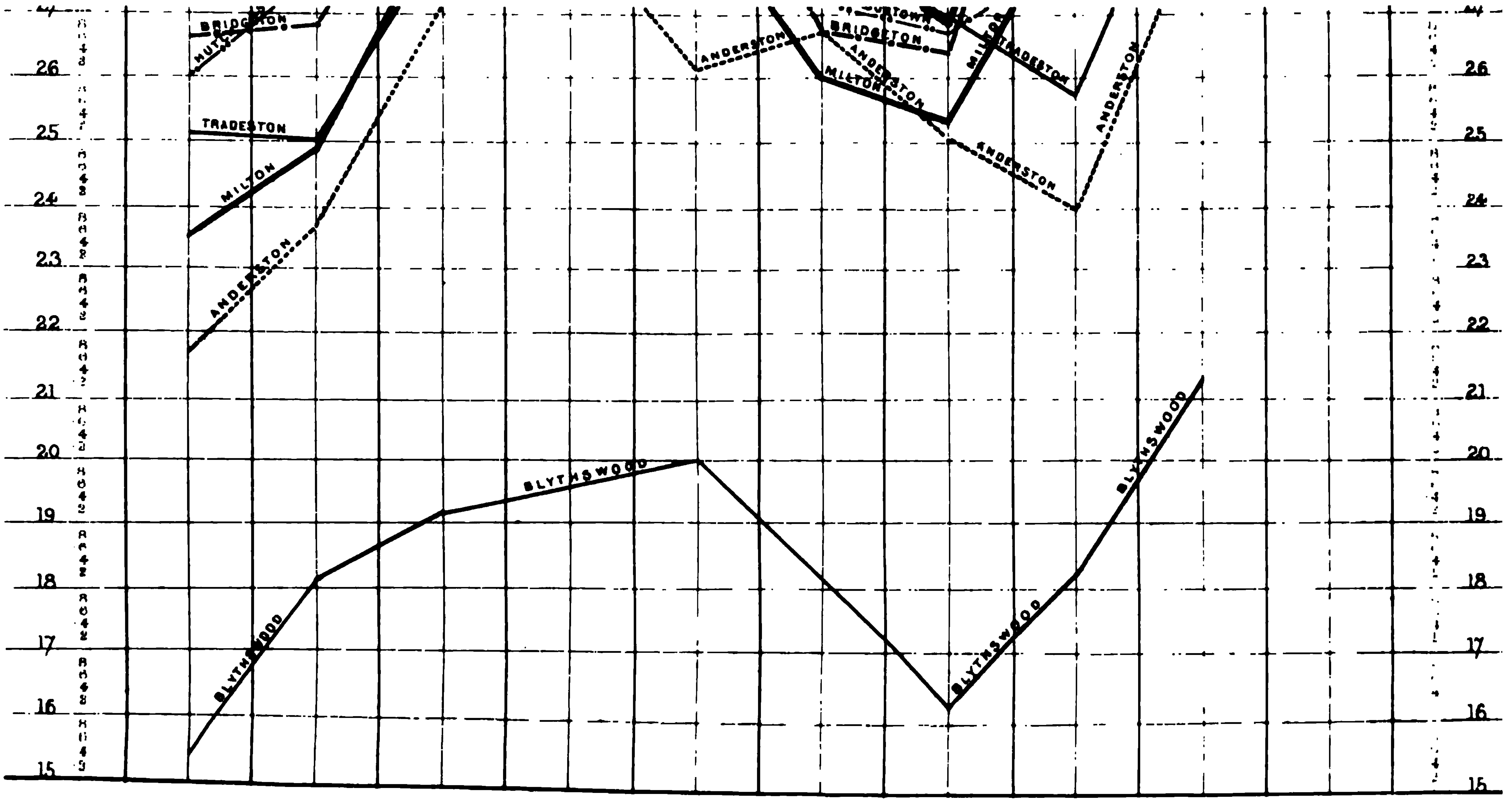
Blythswood.	
Deaths / Population	Death Ra[te] per 1,00[0]
$\frac{440}{28567}$	15·402
$\frac{535}{29426}$	18·181
$\frac{577}{30154}$	19·135
$\frac{604}{30884}$	19·557
$\frac{633}{31604}$	20·029
$\frac{587}{32343}$	18·149
$\frac{538}{33072}$	16·267
$\frac{603}{33801}$	17·840
$\frac{736}{34581}$	21·285

middle of Year.


BRIDGETON
TRADESTON
MILTON
ANDERSTON
BLYTHSWOOD
26
25
24
23
22
21
20
19
18
17
16
15

district where the one sewer passed through, and then, after passing over some of the poorest districts, it shewed itself again where the other passed. Dr. Wallace had stated, in giving the analysis, that the quantity of ammonia contained in this matter was equal to that arising from a population of 40,000.

MR. DUNLOP thought that before coming to the conclusion that the pot ale was the cause of the high mortality, they should reflect that the highest mortality occurred in the summer months, when the sewers were less flushed. He was much struck with the fact that while the death rate in London, of children under one year, was very nearly as high as ours, it would exceed ours if the birth rates were equal to that in Glasgow. In dividing Glasgow into districts, as proposed, for the purpose of taking the rates, it would be important to have a separate birth and death rate analysis.

MR. SMITH explained, in answer to some observations, that he did not wish to say that the pot ale was the cause of the high mortality of Glasgow. He only wished to state that the death rate was higher all through the district the pot ale ran; and, further, it was only where the sewer was shut up that this was the case—not where it ran open, as in the Kelvin. In winter the people were forced to go into their houses, and there breathed the bad air from the sewers, and hence the higher death rate from that cause in winter.

COUNCILLOR COLLINS had often been struck with the low death rate of Newcastle, which was as smoky as Glasgow.

DR. FERGUS would like to know what mode they had of disposing of their excreta in Newcastle. There was infinitely more smoke there than in Glasgow, and 45 per cent. of all the alkali manufactured in the United Kingdom was made there. They poured the refuse from all these works into the river in a much more offensive state than was done in this city, and yet the salmon came up the river. The only difference he knew was in regard to the excreta.

MR. M'TEAR said that the immense current on the Tyne must produce a very large amount of ventilation. The chemical works in Newcastle proper were very few, but they extended down the river for miles. He had seen salmon caught quite near to a pipe pouring into the river chloride of manganese.

DR. LYON very much doubted whether it could be proved that offensive smells produced disease. The inhabitants of Broomielaw were as healthy as those of any other district of the city.

The PRESIDENT thought that the connection of temperature with the death rate had been much overlooked.

Mr. Macfadyen having made a few remarks in reply to some of the observations, the subject was dropped.

XI.—*On some Sources of Error in Volumetric Analysis.* By Robert R. Tatlock, F.R.S.E., F.C.S.

Abstract of a Paper read to the Chemical Section, 19th December, 1870.

The object of this note is to point out a few of the many sources of error in Volumetric Analysis, and to indicate the best means of avoiding them. The accurate and observant experimenter will find little that is new in what I have to bring forward; but, at the same time, I intend to refer mainly to such circumstances as are but too frequently overlooked by the ordinary analyst.

In the first place, I would seek to direct attention to a source of error which, so far as I can ascertain, has hitherto been overlooked by chemists. It arises from the fact that saline solutions contract, as a rule, when mixed with water, the extent of the decrease in volume depending on the nature of the saline substance dissolved, as well as on the strength of the solution. This fact, although it does not seem to have been recognized in principle till within a comparatively recent period, appears to have been discerned in practice for a very long time back; as otherwise there would have been no necessity for the elaborate tables shewing the proportions of salts, of acids, and of alkalies in solutions of different densities, with which many chemical works, even of old date, are amply provided. Much misapprehension prevails, even at the present time, regarding the nature of solution, but more particularly in connection with its effect on volume. In the *Chemical News* of 15th July, 1870, we find a paper by S. Beswick, of Boston, U.S., calling attention to the circumstance that Swedenborg was the first to announce that when saline substances were dissolved in water, there was *no increase in bulk*, the volume of the solution being exactly the same as that of the water employed,—a doctrine which was afterwards promulgated by Dalton. The author of that paper seems to take the doctrine for granted, and claims for Swedenborg the honour or credit of the discovery. A very superficial glance, however, will

shew that the hypothesis is altogether a mistake; for, if it were true, the density or specific gravity of a saline solution would at once indicate the proportion of solid matter it contained, which, we know, is very far from being the case. On the contrary, it has been shewn by Persoz that the volume of a saturated saline solution is just the volume of the water *plus* the volume of the salt. It is also certain that when the saturated solution is mixed with water, a reduction in volume takes place,—the sum of the volumes of the saline fluid and the water being appreciably more than that of the product after diffusion has occurred. This fact may be made apparent in various ways. For example, if we mix together equal volumes of a salt solution of any given gravity, and of water, and test the gravity of the resulting mixture, we find it higher than that of the mean, which of itself demonstrates that contraction has taken place, and we have thus a most refined method of determining the *amount* of condensation, by accurately taking the gravities of the solutions at different strengths. The actual shrinking may be seen by half-filling a large bulb of known capacity, provided with a long, narrow graduated stem, with saturated solution of common salt, and carefully filling completely to one of the marks on the narrow neck, with water, taking care that the liquids do not diffuse. The level of the water having been accurately observed, by swaying the flask to and fro for some time, in order to mix the two liquids, the fluid is seen to run down the stem to such an extent, that with a bulb capable of holding 1 litre, and having a stem of 1 centimètre internal diameter, a difference of level of from 10 to 15 centimètres may be observed. Nor is this diminution in volume due to the slight reduction in temperature which is usually observed to accompany the diffusion, as that is generally too small to account for any appreciable alteration in volume. I have made very many trials of various saline solutions in this direct way, but the following example—that of sulphate of ammonia, which is selected on account of its giving unusually marked results—will serve to give some idea of the extent of these contractions:—

Volume of Sulph. Amm. Solution used.	Volume of Water used.	Specific Gravity of Sulph. Amm. Solution.	Solid Matter per cent. by Weight.	Solid Matter per cent. by Volume.	Contraction per cent. of Total Volume.
1	1	1·2500	43·5	54·3	1·165
1	1	1·1394	24·5	27·9	·361
1	1	1·0756	13·5	14·5	·115
3	1	1·2500	43·5	54·3	·787

The diminution in bulk which takes place when various fluids are diffused in water is well known. The practical distiller, in making down a high strength of spirit to a lower, expects to find a smaller volume of product than that of the sum of the two fluids used. It is also quite understood that strong sulphuric acid, when mixed with water, gives contraction; but I was not prepared for the result of some experiments which shewed an immense contraction, even while the fluid remained at 100° C.

Only fifteen years ago, Michael and Krafft denied that any diminution in volume takes place when saline solutions are mixed with water. How they could come to that conclusion in the face of the fact that a mixture of given bulks of saline solution and of water is not a fluid whose density is the mean of the two, it is difficult to conceive. Later experiments by Kremers, Schiff, and Persoz shew that contraction takes place as a rule; and Schiff mentions the curious circumstance of non-contraction in the case of ammonium chloride. More minute experiments are required, however, before the latter exception can be considered established.

The circumstances attendant upon these effects are very complicated, and in the present state of science the results cannot altogether be explained. In the case of saline substances, the shrinking is usually accompanied by a slight reduction in temperature, whereas we naturally expect an elevation, as in the examples of alcohol and of sulphuric acid. According to observations by John Tatlock, sugar solutions and glycerine solutions contract and give heat on diffusion with water.

What the analytical chemist has chiefly to do with, however, is the effect of these contractions on the accuracy of his results, when that has to depend to any extent upon the solution of a salt, and the accurate division of the solution. In the ordinary analysis of a mixture of saline substances, such as a commercial potash salt, the method usually, and very properly, followed is to dissolve the substance in water, and filter into a measuring flask. The filter having been washed till the flask is half-full, or more, the solution is made up accurately to the mark with water, and is then thoroughly mixed. It is obvious that contraction must here take place, and that if we do not take this into account, we shall, when we proceed to divide the solution by pipettes, actually draw off a somewhat stronger solution than if no contraction had occurred. It is hardly necessary to observe that this error may to a great extent be obviated,—1st, by using as weak solutions as possible, as it is manifest, from the example given, that strong solutions contract far

more for a given weight of solid substance than weak ones; and, 2ndly, by mixing the saline solution thoroughly with the water before making quite up to the required bulk.

Another source of error, and one I believe not often taken into account, arises from the fact that graduated vessels made to *deliver* fixed volumes of water do not deliver exactly corresponding volumes of saline fluids. Hence we do not obtain the exact amount of solid substance which we expect, if we base upon the water-delivering-capacity of the pipette or other vessel.

The following tabulated statement of the results of a few trials, with solutions of common substances, will shew that the adhesion of a strong solution to the glass surface is very great, and quite sufficient to disturb the accuracy of results in most ordinary cases. The vessel used was a pipette which delivered 1,000 grains of water, at 60° F., by draining for 10 seconds, and then touching the delivered water twice with the extreme point:—

Solution Used.	Specific Gravity.	Solid Matter per cent. by Weight.	Pipette used.	Weight of Solution delivered.
Sulphate of Ammonia,	1·2500	43·5	1000 vol. grs.	1247·4
Chloride of Potassium,	1·1812	24·5	" "	1179·3
Chloride of Sodium,	1·2072	26·4	" "	1204·4
Sulphate of Zinc, .	1·4264	53·0	" "	1419·6
Chloride of Ammonium,	1·0724	26·0	" "	1071·9

It is obvious from these results that a pipette delivering 1,000 grains of water does not, as we should expect, deliver a quantity of fluid corresponding with the specific gravity, but sensibly less; and hence a pipette must be graduated to deliver, not water, but the particular saline solution to be employed; that is, the volume of the fluid delivered must be such that the weight will be identical with the gravity. As in the error caused by diffusion-contraction, the difference is here much greater in strong solutions, for a given weight of solid salt, than in weak ones; but a reference to the above example of chloride of ammonium will shew that the difference depends upon the specific gravity of the solution, rather than on the amount of solid matter which it contains. Weak solutions are therefore to be preferred in all cases.

Another source of error, but one more generally recognized, arises from the fact that saline solutions expand more than water for equal increments of heat, and, as a necessary consequence, contract more than water, by reduction of temperature. The expansion increases

very rapidly with the strength of the solution; so that we should either work as near to the standard temperature as possible, or, where that is not admissible, with weak liquors.

The author next referred to the defects of graduated vessels, as usually sold, and exhibited and described an apparatus devised by Mr. James Chalmers, of Iquique, Peru, by which a tube, although of unequal calibre throughout, could be graduated so that each division delivered exactly an equal volume of the same fluid.

XII.—*Note upon Scientific Education in National Elementary Schools.* By Henry W. Crosskey, F.G.S.

Read before the Society, March 8, 1871.

I do not propose to enter upon the questions of political organization and sectarian management involved in the establishment of a national system of education. The election of School Boards, with authority to levy a rate, will, under any circumstances, direct public attention to Parochial and National Schools. Up to this time educational subjects have been very much regarded as matters of technical dispute between the Privy Council and teachers and managers of schools, while institutions such as the Philosophical Society have taken little interest in the standard of teaching throughout the country.

In the midst of the outcries of contending sects, the calmer voices of learned societies should now be heard insisting upon the necessity of securing a certain amount of scientific education for all classes of the community. The necessity of affording at least elementary scientific education in every national school rests upon many grounds, both industrial and social. The elements of science, taught by specimen and diagram, especially quicken the activities of a child's mind. There must be a certain amount of drudgery in mastering the rudiments of knowledge; but science gives an insight of educational value into the world which will be opened when the weariness of task-work is overcome. No one can exaggerate the mental life which would be aroused in a Highland school on the

shore by the introduction of a microscope, or a lesson on the habits of the common objects of the sea. The mental discipline of science is as real as that afforded by any other branch of study; and schools should offer methods of discipline adapted to different orders of minds. I do not propose to take part in the old fight between classical and general culture, but venture to put this third proposition—that all minds cannot be cultivated in the same way; and that the best achievements of many will be in another direction than classics. Lessons in science will create scientific tastes of the largest social value. The miner, the fisherman, the quarryman in the country, the operative and the clerk in the town, will find a new interest in life, and live in a world of nobler interests. A merely *technical training* for business purposes will not supply the want of an early awakening of scientific tastes. The introduction of science into educational training will prevent it from being regarded merely as a clever way of making more ingenious machinery, and render it a culture. I need not remind this society that the most useful discoveries have really sprung from the most abstract speculations. I am advocating, therefore, not merely a technical education, to make man a better machine for the making of better machines (important as this undoubtedly is), but a higher and nobler culture, out of which technical skill will naturally spring. Assuming the importance of scientific education in national schools, I desire, especially, to invite the attention of the Philosophical Society of Glasgow to the method by which it may be secured; because *Scotland* is prepared to do what it will take many years of labour to persuade the educationalists of England is possible or even desirable.

During my recent residence in England, I have been more and more impressed with the advantages which have accrued to Scotland from two things, which I trust she will never permit what, although an Englishman, I must call *English meddling*, to take away or hamper:—(1.) The range of subjects taught at parochial schools, so that they lead to the University; (2.) The penetration of University culture to every rank of life, so that the aristocracy of knowledge has a chance of conquering the accidents of fortune. Through these two causes the introduction of scientific training in national schools will become comparatively easy, if bodies like the Philosophical Society will exert their just and honourable influence. There is, however, a document called "The *Revised* Code;" and there is an Administrative "Department." The general public and members of learned societies have regarded disputes between this mysterious

"Department" and schoolmasters, about the "Code," rather as professional squabbles than matters of serious concern.

The time is rapidly approaching when a Department and a Revised Code, specially arranged for Scotland, will become of supreme importance to all men interested in the higher education of the people. The Revised Code, which up to this date has been in force in England, makes pecuniary results dependent on examinations in a series of standards: in Scotland, although the pecuniary clauses do not apply, the examinations are taken.

Few, probably, are aware of the astounding simplicity of the highest or Sixth Standard, as compared with the demands of any German School, or with any Standard of real education; yet even this proves a hard stumblingblock.

In the English examinations of 1869, 1870, taking children over ten, out of every 100 only 63·5 passed without failure, although 118,809, or 44·6, were examined in the *three* lower standards; while those who passed without failure in the three higher standards were only 32 out of the 100!

Out of every 1,000 children qualified by age and attendance, only 98 were presented in the two higher standards, in place of 319, who ought to have been prepared to pass such an examination at the close of what must be to most of them their brief period of school life. There is a common practice of keeping back from examination the children who are duly qualified by age and attendance, or of presenting them in standards too low for their age.

In addition to the "Standards," some specific subjects of secular instruction are provided for in the time-tables of the schools, and are also subjects of examination; but the advantages of securing a large number of passes are greater than those to be derived from carrying on the education of the school to any high special attainments.

Let us see how the system of examination in the "Standards" works in Scotland.

With respect to the three kinds of schools which have undergone the test of the Standard Examinations—*parochial, privately endowed, subscription*—in the subjects that go *beyond* the standards, the advantage is assignable to the parish schools. (Gordon's *Report for 1869*, p. 371.)

The parochial teachers are qualified to give instruction in these subjects; "they have pleasure and a certain pride in occupying themselves in such subjects; they desire to keep up the traditionary

character of the schools; and in this they are generally supported by the people, well pleased to have a school of that order among them."

This higher instruction, however, is languishing, because there are no pecuniary advantages derivable from it. To keep back within certain limits doubtful pupils, produces no loss, while it increases the percentage of passes; so that the suspension of the pecuniary part of the Revised Code in Scotland tends to diminish the presentations, especially in the higher subjects.

Mr. Kerr reports in his district (p. 391) that Geography and Grammar are taught in almost all the schools, *not probably to the same extent* as before the introduction of the Revised Code, but still satisfactorily. "These branches are naturally regarded as only second in importance to the standard subjects; but the cases are few where they are sacrificed."

Is it not a deterioration to have them sacrificed at all? and does not the commencement of this tendency shew a reversal of a wise educational feeling?

The following conclusions appear justified:—

(1.) The people of Scotland are generally proud of schools in which the higher culture is given.

(2.) The schools most nearly national, although under one ecclesiastical management, are really those in which the higher culture has been most carefully retained.

(3.) The general result of the examinations in the "Standards" has been to deteriorate the general character of the education of the country.

I believe, therefore, that the introduction of higher subjects would be satisfactory to the people; and that science could take its place in Scottish national schools, provided that it is not checked by Government encouragement of the lower culture chiefly or only; and *this* is the danger against which practical warning is needful.

In the *new English* Revised Code, scientific subjects are included among those specific subjects for which a grant of 3*s.* per subject may be made for every day-scholar, presented in Standards IV.–VI., who passes a satisfactory examination in not more than *two* of such subjects.

Since these specific subjects include geography, grammar, history, &c., it is evident that the natural sciences stand little chance, when not more than *two* such subjects are to be selected. Geography, grammar, history, can hardly be left out of education. The method

of producing respect for the higher standards and the subjects beyond them would, I suggest, be—1st. To increase the grant (if the system of payment of results is perpetuated) in proportion to the standard and the subject. 2nd. To have more than two extra subjects fairly paid for. It is not at all necessary that the schoolmaster should be the scientific teacher. One scientific teacher might visit many schools.

The introduction of science would cause modern schools to stand in the same relation to modern knowledge that the parochial schools occupied to the state of knowledge at the time of their foundation; and could be readily accomplished, if any educational party has the real courage of an intellectual purpose. The idea of *common* schools for *common* people pervades all English educational legislation. My great hope is that Scotland may teach a better lesson.

I would respectfully urge upon the members of this Society the importance of exercising the greatest watchfulness that, under the Code which will be issued for Scotland, when the Lord Advocate's bill becomes law, the standard of education should be uplifted, and not lowered, and of taking definite steps to secure the positive introduction of science into all national schools.

Discussion on the Preceding Paper.

Mr. James R. Napier hoped that the encouragement proposed to be given to elementary education would be such as not to discourage the teaching of the higher branches. The difficulty of establishing in the public schools of Glasgow classes for the higher mathematics, so essential to a successful engineer, was so great at present, owing to university arrangements, as almost to preclude their being taught. State encouragement to the elementary, and none to the higher branches, will certainly increase this difficulty. It will virtually be a tax upon those who wish to increase their knowledge—upon those who are the pioneers of a nation's wealth.

Professor Young was highly gratified that Mr. Crosskey had introduced the subject. At the present time it was important for them to consider in what direction education was to be promoted during the next five or ten years. The evidence we had of the gradual sliding down of education, as conducted in many of the schools in the west of Scotland, was sufficient reason for its being considered at present. Upon this point he had already expressed

his opinion, with what had been considered perhaps a little coarseness, in the introductory address delivered to the University at the beginning of last session. The reason for the strength of language then used was the somewhat deplorable circumstance that, notwithstanding the length of time the regulations had been in existence for raising the character of the preliminary education for medical students, these men came up just as they used to do five or six years ago. Nay, there seemed rather a tendency in the wrong direction. He had ascertained that the cause of this was the direction which Mr. Crosskey had indicated—the lowering of the standards for some years. Any one who took the trouble of examining the papers prepared by the Education Department for some years back, would see how one subject after another had been allowed to slip out; and it was matter of surprise that the Government net, so wide in the mesh, did occasionally happen to trap an inefficient teacher. This opinion was not confined merely to people who, like himself, looked at this subject from the outside. Those who were engaged in the work had themselves borne abundant testimony, and it was to be regretted that the testimony already borne had received so little attention. Two or three years ago there was a return published from the clergymen and heritors in Scotland upon these schools, and the testimony was throughout excessively strong, that the schools had been slowly, steadily degenerating. It was impossible to get a good system of education so long as the "Revised Code" was in operation. Professor Huxley had spoken of education as a ladder beginning in the gutter and ending in the university; but the ladder might be a short one, or it might be a long one. It was gradually getting shorter, and universities were compelled to bring themselves nearer to the gutter. In the universities in Scotland there was no prospect yet of putting an end to the existence of junior classes. It was a state of things which every teacher was agreed should come to an end; and those who were compelled to undergo the drudgery of these classes would be glad if it did. This was impossible, so long as the schools remained in their present condition. Practical suggestions it was perhaps not easy to make; and he would feel it presumptuous to make suggestions where he had no practical experience. They might stir up the people; and it was in this point of view that the discussion in the Society was of great value. He hoped that it would not be long before the example would be followed, which, he believed, had been set by one or two bodies of school managers in Glasgow, to lay aside the New Code and its Standards altogether.

Mr. Mayer said he had been long identified with a school in which the teaching of science systematically had been a prominent feature. From that school, which was an ordinary elementary school, they had turned out a considerable number of doctors, several of whom had passed their examinations in the University with much credit to themselves. He learned that their minds had in many cases been directed in this way by the scientific instruction they had received in the course of their ordinary curriculum. He might mention that there had been in operation for the last twelve years in England, Scotland, and Ireland, a system for aiding the industrial classes of the country to obtain scientific instruction; and this system applied to elementary schools as well as to public institutions, whether the classes were conducted by day or in the evening. Ever since this system had come into operation, they had had pupils examined by Professor Huxley and other eminent men in other branches of science; and he was not yet informed that this system had been done away with. The new Code provided for the introduction of science into ordinary schools; and if the science scheme was not to be abolished, they would see that there was likely to be a curious clashing of purposes. It was certainly not necessary that the teacher of an elementary school should be proficient in any branch of science, so that it should be taught. It might be arranged so that persons who devoted themselves to science should get the teaching of these branches, so that the ordinary teacher might receive Government aid for teaching the elementary branches, the science teacher being paid through the Science and Art Department. They found that boys and girls of twelve years of age were quite able to take in the amount and kind of instruction that would enable them to pass through those very fine meshes which Professor Huxley made for them. They could not get through without knowing something both of the facts and principles of science; and Professor Huxley was careful to trap them.

The President thought it was of the utmost importance at the present time that something should be kept in view about maintaining the Scottish standard of education. No doubt, the lowering of Scottish education had been due to the action of the Privy Council. The Privy Council Code completely traversed our old Scottish system of having one class of teachers for the rich and poor. The great difficulty in regard to teaching science in common schools was the want of properly qualified teachers. Unless natural science was taught by means of specimens, and by a teacher who could demonstrate his lessons in the field, it

was practically useless. The mere æsthetical advantages of science teaching were beyond all power of statement.

He highly approved of what Professor Young had said. The only way to improve the schools was to take away the elementary classes from the universities. It was in vain to say that the schools must first be raised. The thing could be done in two or three years by the universities having an entrance examination, and allowing none to enter who could not pass that examination.

In regard to the training of those who were past school age, it was proposed to make the Mechanics' Institutions technical schools, and thus raise the standard of knowledge among our workmen. It was a question with him if the people of this country could be raised to the ability of the French and Italians in invention and design. He thought it was a question of race. If such tastes were inculcated at an early age, a great moral good was done, because the youth was given a means of employing his time so as to keep him from lower pleasures.

MR. NAPIER proposed, and it was unanimously agreed, to appoint a committee, with powers to add to their number, to consider this question, and, if necessary, take action in connection with the legislation for the teaching of science in elementary schools in Scotland.

MR. CROSSKEY said that the real work for this committee would be to watch when this Code was introduced into the House of Commons, and within two weeks of that time, before it became law, to get some Scotch member to challenge it.

MR. JEFFREY thought the President was rather severe on the universities. He did not see that a preliminary examination of students would do any good. They would merely be thrown back; and if the schools could not give them a proper education, their progress would be entirely interrupted. The proper thing was to raise the standard of schools, and force the universities to ascend.

The PRESIDENT said it was never intended that the higher preliminary examinations should be gone into at once, but that the schools should be warned that such examinations were to be held, and the system thus introduced gradually.

XIII.—*On the Chemical Constitution of Paraffin.* By T. E. Thorpe, Ph.D., Professor of Chemistry in the Andersonian University, Glasgow.

Read before the Society, March 13, 1871.

The author reviewed at some length the views which have been put forward respecting the constitution of paraffin, and concluded that the balance of opinion seemed in favour of the supposition that paraffin is a member of the $C_n H_{2n} + 2$ series of hydrocarbons. He then proceeded to describe the results which he had up to the present obtained, in conjunction with Mr. John Young, in studying a reaction, which promises to throw much light on this subject. When paraffin is exposed to a high temperature in a closed vessel, it is almost completely resolved, with the evolution of but little gas, into hydrocarbons, which remain liquid at the ordinary temperature. This reaction was repeated on the large scale, and from 3½ kilogrammes of paraffin, melting at 46° C., prepared from shale, nearly 4 litres of liquid hydrocarbons were obtained. The apparatus employed in the conversion consisted of two cast-iron mercury bottles, connected together by an iron pipe, in which were fixed a stopcock and pressure gauge. One of the bottles was charged with the paraffin, and was heated over an ordinary coal fire, the heat being so regulated that a pressure of 20 to 25 lbs. was maintained throughout the operation. At first the iron pipe was so inclined that the products of distillation could flow back into the heated bottle; but after an hour's heating, it was so arranged that the volatile portion could flow over into the second mercury bottle, which acted as a condenser. In about four or six hours the operation was concluded, and the distillate had the appearance of a magma of oil and unaltered paraffin, melting at an extremely low temperature, the warmth of the hand being sufficient to liquefy it. On distillation it commenced to boil at 18° C.; but the quantity coming over below 100° was comparatively small,—by far the greater portion boiled between 200°–300° C. A preliminary separation shewed that the four litres were made up of hydrocarbons, boiling from—

	Litres.
200°–300°,	2·7
100°–200°,	1·0
Below 100°,	0·3
	4·0

The portion boiling below 100° was first attacked. By repeated rectifications over sodium, this portion was at length resolved into three perfectly colourless fractions, boiling constantly at 32°–34°, 65°–68°, and 94°–97°. The liquid boiling between 32°–34° may either be amyl-hydride or amylene, or a mixture of both. In order to decide this point, recourse was had to the different behaviour manifested by these bodies towards bromine. To the portion boiling at 32°–34°, bromine was added slowly, drop by drop, so long as it continued to disappear; as soon as the colour of the bromine was persistent, its addition was interrupted. Bromine attacked the liquid with great energy, each drop hissing like a red-hot iron on coming in contact with the hydrocarbon; and it was necessary to moderate the action by cooling the liquid by a freezing mixture of snow and salt. On submitting it to distillation, the liquid commenced to boil at 32° C., and a small quantity came over below 50°, after which the thermometer rose rapidly to 184°, and the whole of the brominated compound came over at 184°–188°. This substance is amylene dibromide $C_5 H_{10} Br_2$, the boiling point of which has already been determined by Wurtz to be about 180°. The portion boiling between 32°–50° yielded, on rectification, pure amyl-hydride, boiling at about 34°–35°.

The same experiment was repeated with the fraction boiling between 65°–68°. This might be hexyl-hydride, or hexylene, or a mixture of both. Bromine disappeared instantly on adding it to the liquid carefully cooled, and on distillation, the liquid began to boil at 64°, and the thermometer rose rapidly to 195°, when the heavy bromine compound distilled over between 195°–198°. This was hexylene bromide $C_6 H_{12} Br_2$, the boiling point of which, according to Pelouze and Cahours, lies between 192°–198°.

The fraction boiling between 94°–97° may be heptyl-hydride or heptylene, or a mixture of both. It was heated with bromine in the manner described, and exactly analogous results were obtained. The liquid was found to be heptylene and heptyl-hydride.

An attempt was made to determine the relative amounts of the olefines and hydrides present in these mixtures, by means of the bromine reaction above-mentioned, when it was found that, after allowing for the conditions of the experiments, the proportions of the two series of hydrocarbons were sensibly equal.

Diligent search was made for Benzol and the Hexoylene of Caventon — representatives of $C_n H_{2n}-6$ and $C_n H_{2n}-2$ series,—but without success. The portions lying between the fractions boiling at 65° and at 95°, in which these bodies would be found, did they

some, were merely mixtures of the hydrides and olefines, into which, by repeated fractionations, they were resolved. No solid bromide of hexylene could be obtained, nor was the least trace of benzol detected.

The author, in conjunction with Mr. Young, is now engaged upon the portion boiling between 100°–300°; and so far as they have gone, the results corroborate the conclusion that these hydrocarbons, produced by the splitting up of paraffin, are mixtures of hydrides and olefines. They have isolated octyl-hydride and octylene, boiling about 125°, and have just obtained a liquid boiling constantly at about 140°, which may be a mixture of nonyl-hydride and nonylene. They have searched in vain for œnanthylidine, boiling at 107°; for toluol, boiling at 112°; and for caprylidine, boiling at 135°. There was absolutely no liquid boiling between 95° and 125°—an additional confirmation that members of the benzol and acetylene series were absent.

As their experiments upon this subject are not completed, the authors deem that it would be premature at present to hazard any interpretation of their results. They think, however, that they will be able to demonstrate that the fact of its yielding olefines, on decomposition, is not incompatible with the assumption that paraffin is a member of the $C_n H_{2n+2}$ series of hydrocarbons.

XIV.—*Notes of Analyses of an Earthball and Intestinal Calculi from the Horse.* By Mr. James F. Stark, F.C.S.

Read before the Chemical Section of the Society, March 27, 1871.

The following serves merely to bring under your notice two analyses I had lately occasion to perform. The earthball was extracted in the end of last year from the large intestine of a horse in the possession of Messrs. Charles Tennant & Co., St. Rollox. In diameter it measures about 5 inches, and weighed, when entire, 2 lbs. This, large and weighty though it appears, is, notwithstanding, nothing very unusual. I have here the half of a similar earthball, of equally large dimensions, taken from a horse belonging to the

Coltness Iron Co.* Breschet, again, mentions one measuring 9¼ inches in diameter, and weighing 19 lbs. All these, however, are dwarfed alongside of one which was lately taken from a young Irish horse, and which had attained to the almost incredible weight of 27 lbs.

The section of this earthball shews that the materials of which it is composed have been deposited under various changes of circumstances, at one time growing solely by accretion of mineral matter, at another time by mineral matters intermingled with substances of organic origin. In the analysis a full section of the ball was taken, so as to ensure a fair average sample.

Magnesia,	13·585	83·197
Ammonia,	8·828	
Phosphoric Acid,	24·109	
Water (combined),	36·675	
Lime,		0·239
Alumina,		4·171
Ferric Oxide,		1·033
Soda,		0·358
Phosphoric Acid,		0·189
Carbonic Acid,		0·015
Sulphuric Acid,		0·465
Silicic Acid,		5·202
Sodium Chloride,		0·490
Organic Matter,		4·686
		100·045

The remarkable feature in this analysis—indeed, that on which its whole interest centres—is the very large proportion of ammonio-magnesic phosphate present.

Shortly after performing this analysis, I had the fact of the formation, to a large extent, of this ammonio-magnesic phosphate within the intestines of horses confirmed, by receiving several calculi which had been passed by a horse, and which the following shews to have been almost entirely formed of this salt. They are of a uniform crystalline structure, and average about 1 inch in diameter.

Ammonio-Magnesic Phosphate:—

$Mg_2 P_2 O_7$,	44·504	
$(NH_4)_2 O$,	10·424	
$12 H_2 O$,	43·301	98·229

* This ball contained 72·903 per cent. ammonio-magnesic phosphate.

Organic Matter:—		
Soluble in H Cl., ...	0·801	
Insoluble „	0·910	1·711
Silicic Acid, ...		0·044
		99·984

As to the condition of the blood necessary for the deposition of this ammonio-magnesic phosphate, I have not spent time in speculating: such comes more within the range of the studies of the physiologist. We see plainly enough, however, that, as in this case, a small nucleus presenting itself—being detained, probably, in some cavity—we have this salt thereon deposited. Now, if this goes no farther, no serious damage is done. Such calculi seem to pass readily through the intestines, being smooth on the surface, and of a shape calculated to facilitate such a passage. It is only when the calculus assumes a nature similar to this earthball that danger ensues to the animal—only when the ammonio-magnesic phosphate is intermingled with adventitious substances. How this intermingling of mineral and organic matter takes place, I think I may be able to shew you. If we take a quantity of chopped hay, and sift the finer particles away from it, re-sifting these several times through finer sieves, and lastly through muslin, we arrive at a very finely-divided dark-coloured mass, exactly similar to that existing in the earthball. Again, on boiling a small quantity of this earthball in water, we find a certain amount of seemingly albuminous matter separate out, floating on the surface of the liquid. If we then suppose the surface of the calculus to be in part coated with this albuminous matter, any particles of this fine dust coming in contact with it would at once firmly adhere (indeed, examined under the microscope, this dust seems exactly fitted for such a work). Over this more ammonio-phosphate would be deposited, and so on, the mass gradually increasing in bulk. A substance similar to this fine dust is likewise found on grain, especially on oats, and is, in the latter case, sometimes separated, to the great improvement of the meal. From this substance millers' horses in some districts are very subject to intestinal calculi. But in this case the horses did not always suffer alone. Wollaston and Dr. Munro, tertius, fully investigated, in their *Morbid Anatomy of the Human Gullet*, published 1811, a peculiar calculi then endemic to Scotland, the frequent occurrence of which amongst the population was assigned to the

abundant use of oatmeal. Dr. Maclagan, in the *London and Edinburgh Journal of Medical Science* for September, 1841, speaks of such as growing less common; and now, I suppose, they have nearly, if not altogether, disappeared.

And now, as to the practical application of this, I have only one remark to make. What I have said points, I think, clearly to the necessity there is for thoroughly sifting all hay, as well as grain, used in the feeding of horses. If this practice were regularly followed by the large employers of horse-power in our towns, the frequent loss of horses from earthballs, at present in many cases sustained, would, if not altogether ceasing, be at least materially diminished.

XV.—*Preliminary Notice on the Action of Chloride of Zinc upon Morphia and Papaverine, and on the Action of Nitrous Acid, Bleaching Powder and Hydrochloric Acid upon Morphia; and some Notice of a new Opium-base.* By MR. E. L. MAYER.

Read before the Chemical Section, March 27, 1871.

Action of Chloride of Zinc.

WHEN morphia is heated with $Zn\ Cl_2$ to 125° for about twenty minutes and the mixture thrown into water, a body separates, which, if dissolved in hot water, precipitates again on cooling as a non-crystalline mass. From its formation and reactions, I consider it to be probably morphia, less $\frac{1}{2}\ H_2O$; in its physiological action it resembles and probably surpasses apomorphia.

If the mixture mentioned above be heated for a longer time and to a somewhat higher temperature, saturated with $Na_2\ C\ O_3$, treated with ether, and the ether shaken up with strong $H\ Cl$, crystals are obtained, which, re-crystallized and dried in a water bath, gave on analysis—

	Calculated.		Found.
C_{17}	204·	67,22·	67,12·
H_{18}	18·	5,93·	6,24·
N	14·		
O_2	32·		
Cl	35·5		
	303·5		

which agrees with the formula $C_{17}\ H_{17}\ N\ O_2,\ H\ Cl$.

This is the formula of apomorphia, the base obtained two years ago by Drs. Matthiessen and Wright, in treating morphia with H Cl in an open dish on the water-bath for some days, or heating it in a sealed glass tube to 140°-150° C. for some hours. As the body besides has all the properties of apomorphia, further investigations have been considered unnecessary.

This base has been formed in this case from morphia, by abstraction of the elements of one molecule of water.

On heating the Zn Cl_2 containing the morphia to about 170° C., another body is formed. I am still engaged with its investigation, but it is very probable that the action again consists in the removal of more H and O from morphia, in the proportion to form water.

Similarly, papaverine treated with Zn Cl_2 at 125° C. for twenty minutes, gives a liquid which, after dilution with water, saturation with Na_2CO_3 and shaking with ether, deposits crystals by treating the ether with H Cl.

Dried at 100° C., the following numbers were obtained :—

	Calculated.		Found.
C_{40}	480·	65,30·	65,01·
H_{44}	44·	5,98·	6,30·
N_2	28·		
O_7	112·		
Cl_2	71·	9,66·	9,49·
	735·		

leading to the formula $C_{40}H_{42}N_2O_7$ 2 H Cl.

This body corresponds in all likelihood with the morphia base first described, that is, 2 molecules of papaverine have been deprived of the elements of 1 molecule of water.

By heating the Zn Cl_2 and papaverine to a higher temperature, other bodies are formed, with the examination of which I am still engaged.

Action of Bleaching Powder and Hydrochloric Acid.

If morphia is dissolved in dilute H Cl and a sufficient quantity of bleaching powder solution added, greenish-white flocks appear, insoluble in an excess of H Cl. As the mother liquor from body, A below, gives the same reaction, I took that liquid for my starting point.

The new body so formed is obtained in a state of purity by

dissolving it several times in small quantities of boiling alcohol, precipitating with water and at last dissolving in ether and evaporating, whereby an oily liquid is left which changes into a crystalline mass, by standing for some time over $H_2 S O_4$.

Carefully dried over $H_2 S O_4$ I found on analysis—

	Calculated.		Found.
C_{17}	204·	40,75·	40,52·
H_{16}	16·	3,19·	3,37·
N	14·		
O_{10}	160·		
Cl_3	106·5·	21,27·	20,85·
	500,5·		

Its composition is represented by the formula $C_{17} H_{16} Cl_3 N O_{10}$. The basic properties of morphia have disappeared in this body, on the contrary, it combines readily with bases. It also becomes electric by friction.

During its formation some chloropicrin was also produced, as was evident from its characteristic smell.

Papaverine treated in the same manner also gives a similar body,— which I have not yet investigated.

Action of Nitrous Acid.

On introducing nitrous acid, in a *very* rapid stream, into water containing pure morphia, a clear brown liquid is obtained, which, immediately filtered, produces a yellow precipitate (A). After this was washed, first with cold water, then with large quantities of alcohol and dried over $H_2 S O_4$ I obtained the following results :—

	Calculated.		Found. I.	II.	III.
C_{17}	204·	61,44·	61,86·	61,69·	
H_{20}	20·	6,02·	6,42·	6,29·	
N_2	28·	8,43·			8,74·
O_5	80·				
	332·				

These lead to the formula of nitrite of morphia. But I have every reason to consider it to be a nitroso-compound and give it the formula $C_{17} H_{18} (N O) N O_2 + H_2 O$.

Indeed, by drying at 125°, it lost—

	Calculated.		Found.
$C_{17} H_{18} N_2 O_4$	314·		
$H_2 O$	18·	5,42·	5,40·
	332·		

and gave by combustion—

	Calculated.		Found.
C_{17}	204·	65,00·	64,95·
H_{18}	18	5,74·	5,74·
N_2	28·		
O_4	64·		
	314.		

This corresponds with the formula $C_{17} H_{18} (N O) N O_3$.

If this body A be boiled with alcohol, or dissolved in large quantities of boiling alcohol and the latter evaporated, the body (B) left has lost half its water. The following are the results of some analyses of this body, dried at 106°-110° C.:—

	Calculated.		Found. I.	II.	III.	IV.
C_{34}	408·	63,15·	63,04·	63,04·	63,18·	63,22·
H_{38}	38·	5,88·	6,23·	6,19·	5,99·	6,34·
N_4	56·					
O_9	144·					
	646·					

$2 (C_{17} H_{18} (N O) N O_3) H_2 O$.

But if the body A be boiled with water, a totally different reaction takes place. It splits into a body soluble in water (C) (which I have not yet properly examined) and into an insoluble one (D).

The latter dried at 110° C., gave the following numbers on analysis:—

Calculated.						Found. I.	II.	III.	IV.
C_{17}	204·	67,77.	C_{17}	204.	68,00.	67,72.	67,62.	67,80·	
H_{19}	19·	6,31.	H_{18}	18.	6,00.	6,40.	6,31.	6,66·	
N	14·	4,65.	N	14.	4,66.				5,07·
O_4	64·		O_4	64·					
	301·			300·					

It has either the formula $C_{17} H_{19} N O_4$, or $C_{17} H_{18} N O_4$, but I am unable at present to say which is the right one.

If dilute $H_2\,S\,O_4$ be poured upon the body D, an inodorous gas is evolved. The body A, similarly treated, gives out red fumes, but in a tube over mercury yields a colourless gas, which forms red fumes when mixed with air. Both products are insoluble so long as acid is present in excess, or when heated. As I thought it possible that the products might be identical, I instituted some comparative experiments. I decomposed A and B as above described, purified them by decantation and crystallized them finally from water.

E, produced from A, dried at 100° C., gave—

Calculated.						Found.
C_{34}	408·	57,95·	C_{34}	408·	58,10·	57,93·
H_{44}	44·	6,25.	H_{42}	42·	5,98·	6,36·
N_2	28·		N_2	28·		
S	32·		S	32·		
O_{12}	192·		O_{12}	192·		
	704·			702·		

From 100°–125° C. it lost—

Calculated.						Found.	
						E.	F.
$C_{34}\,H_{40}\,N_2\,S\,O_{10}$	668·		$C_{34}\,H_{38}\,N_2\,S\,O_{10}$	666.			
$2\,(H_2\,O)$	36·	5,11·	$2\,(H_2\,O)$	36·	5,13·	5,13·	5,14·
	704·			702·			

The formula for E, dried at 100° C., is therefore either

$$2\,(C_{17}\,H_{19}\,N\,O_3)\;\;2\,H_2\,O,\;\;H_2\,S\,O_4,$$
$$\text{or }2\,(C_{17}\,H_{18}\,N\,O_3)\;\;2\,H_2\,O,\;\;H_2\,S\,O_4.$$

Dried at 125° C., I obtained on analysis—

Calculated.						Found.		
						E.	F.	
							I.	II.
C_{34}	408·	61,08 —	C_{34}	408·	61,26·	61,09·	61,19·	61,39·
H_{40}	40·	5,98 —	H_{38}	38·	5,70·	6,12·	6,20·	6,02·
N_2	28·		N_2	28·				
S	32·		S	32·				
O_{10}	160·		O_{10}	160·				
	668·			666·				

F, dried at the same temperature, gave—

		Calculated.				Found.
$C_{34}H_{38}N_2O_6$	570		$C_{34}H_{36}N_2O_6$	568		
H_2SO_4	98	14.67	H_2SO_4	98	14.71	14.73
	668			666		

These results agree with either of the two formulæ—

$$2\,(C_{17}\,H_{19}\,N\,O_3)\,H_2SO_4 \text{ or } 2\,(C_{17}\,H_{18}\,N\,O_3)\,H_2SO_4.$$

If body A be decomposed with H Cl instead of H_2SO_4, the salt produced is quite similar in appearance and behaviour to those just described, and chlorine is given off, besides another gas. But if this decomposition is undertaken in presence of alcohol, a strong smell of aldehyde appears and no chlorine can be observed.

Experiments made by Dr. Legg in London, shewed that none of these bodies has any physiological effect.

To decide whether these bodies contain H_{19} or H_{18}, I tried to determine the gases evolved by the different decompositions; but owing to the scarcity of my substance, without results. This much I could observe, that with water the body A undergoes decomposition in a vacuum.

As Messrs. M'Farlan in Edinburgh, to whose kindness I am indebted for the material used in the preceding investigations, have liberally offered to supply me with more, I intend shortly to recur to this point, and hope that I shall be able in this way, and by the investigation of body C, to obtain a definite result.

Schützenberger has obtained a body of the same composition as D, but as he describes a hydrochlorate and a sulphate,* it is not probable that it is identical with mine.

To confirm the view that A is a nitroso-compound, I intend to try to convert it into an azo, hydrazo or amido-compound, or replace N O by some other radical.

New Base from Opium.

In the preparation of narceine another body is sometimes found mixed with it, which is left behind when the narceine is purified by dissolving in boiling water.

I have been supplied with this substance by Messrs. M'Farlan, and have found it to be a new well-defined opium base.

It is insoluble in water, sparingly soluble in alcohol, from which

* Jahresbericht, 1865, 446.

it deposits in hard granular crystals. It is also insoluble in ether, but imparts to it a blue fluorescence.

The base dissolves very easily in water containing acids and forms beautiful crystalline salts. The hydrochlorate and sulphate are so soluble in hot water as to form a gelatinous mass on cooling. They also dissolve in alcohol with blue fluorescence.

The salts melt at about 100° C., and decompose at a somewhat higher temperature, becoming redder and redder in colour, and swelling up to a dark-brown brittle vesicular glassy mass.

The platinum salt, which is more stable, is obtained in orange crystals, by mixing a cold solution of the hydrochlorate with $Pt\,Cl_4$. But if the solution of the hydrochlorate be mixed at a higher temperature with $Pt\,Cl_4$, a precipitate is thrown down which at first is soft, but afterwards becomes quite hard. By longer boiling it decomposes.

It is to be hoped that the investigations Professor Anderson commenced, some years ago, on the decomposition of the platinum salts of the organic alkalies, will throw some light also upon this decomposition.

The platinum salt, if dry, can be heated to 135° C. without change. From the solution of its salts $Na_2\,C\,O_3$ precipitates it very slowly, $N\,H_3$ not at all.

The base itself, dried at 100° C., gave the following results on analysis:—

Calculated.			Found.		
			I.	II.	III.
C_{25}	300·	59,64·	59,46·	59,72·	
H_{29}	29·	5,75·	5,95·	5,98·	
N	14·	2,78·			2·79·
O_{10}	160·				
	503·				

These lead to the formula $C_{25}\,H_{29}\,N\,O_{10}$.

The platinum salt dried at 100° C., gave the following numbers:—

Calculated.			Found.
C_{25}	300·	40,25·	39,93·
H_{34}	34·	4,56·	4,62·
N	44·		
O_{12}	192·		
Pt	99·		
Cl_3	35,5·		
	745,5.		

$2\,(C_{25}\,H_{29}\,N\,O_{10}\,(H_2\,O)_2\,H\,Cl)\,Pt\,Cl_4$.

Dr. Legg in London was kind enough to examine this base also and found that a frog was not affected by the subcutaneous injection of 1 grain and that 4·5 grains injected under the skin of a dog weighing 15 lbs., was likewise without appreciable effect of any sort.

To understand the relations of this base, I shall add a short history of the discovery of the chief constituents of opium.

In the fifth century B.C., opium, the dried sap of *papaver somniferum*, was known as a body possessing intoxicating properties. In the eighteenth century, different chemists (Neumann,* Hofmann, Haller, Wedel, Tralles) called attention to the possibility of extracting therefrom a crystallizable *acid* salt, while others, such as Bucholz† (1802) did not succeed in obtaining it.

In 1803, Derosne in Paris published an analysis of opium,‡ in which he confirms the statement of the earlier chemists, in so far as the existence of a crystalline body in opium is concerned, but denies that the salt is an acid one. However, he does not consider it to be a salt, but a peculiar vegetable constituent of opium. His further observations are, in brief, that this constituent of opium is readily soluble in acids and is precipitated *unchanged* by alkalies from its solution. He adds, that he has not succeeded in obtaining the precipitate perfectly free from alkali and consequently, that the body which is identical with that obtained directly from opium, possesses an alkaline reaction.

Two years afterwards the first results§ of an opium investigation by Sertürner, begun in 1804, appeared, which was completed in 1806 ‖ and in which new facts worthy of notice were for the first time reported. In this the discovery of a new acid, meconic acid, is described and that of another body, which exists in combination with the acid and thus distinctly shews that it possesses properties similar to those of the alkalies. In this paper therefore Sertürner announced an entirely new idea, in addition to the discovery of new bodies with well marked characters. Not much notice however, was taken of this and the whole matter sunk into obscurity until the year 1817.

At this time a second investigation by the same chemist appeared,¶ which caused chemists, especially in France, to direct their attention to the subject. Sertürner named the basic substance

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morphium and, in consequence of his observations, speaks of it as a new alkaline base, capable of forming salts which appear to be closely allied to ammonia and differs from the alkalies only in being less powerful. In pointing this out, he had given the true explanation for his observations and whilst Sertürner's labours exceeded all that had been done before upon this subject, a new era was commenced, not only in our knowledge of opium, but in organic chemistry.

Such also was the opinion of Gay-Lussac * when he heard of this discovery and to him the matter appeared so important, that he commissioned Robiquet to make a further examination. However, before Robiquet's investigation appeared, which took place in the same year, Sertürner's investigations were repeated by Choulant in Dresden † and his results confirmed. Robiquet's results ‡ also agree with those of Sertürner regarding morphia. But Sertürner had considered Derosne's *salt*, as he calls it, to be meconate of morphia (he was not acquainted with Derosne's investigation until he had finished his own in 1805), and Robiquet pointed out this error and proved that there were three distinct bodies existing in opium. But he was unable to give any explanation of the nature of Derosne's salt and with regard to meconic acid, fell into the same error as Sertürner had done, namely, that it is capable of being sublimed.

In the following year it was again Sertürner who threw some light upon Derosne's salt § and also upon meconic acid. In a paper he shewed that that salt is not a homogeneous plant constituent as Derosne considered, but a real salt, consisting of meconic acid and a basic body which resembles morphia, but is not able like this to saturate the acids entirely and this accounts for the acid reaction of its salts. Although Sertürner pointed out this second base as a second morphium oxide (in accordance with his theory, in which he regarded at that time morphia as the oxide of a radical, which he called morphium and in which he compared the new body with the peroxides, on account of its slight basic properties) narcotine is clearly recognizable, from the description of the properties of the substance and its salts. Regarding meconic acid he says, in opposition to Robiquet and Choulant, and in vindication of his own view, that the acid obtained by subliming meconic acid is

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different and is a decomposition product, and grounds this upon its properties.

In the year 1818 Vauquelin* attempted to obtain the honour of Sertürner's discoveries for France, inasmuch as in 1814 a memoir of Seguin† was in the press, which he had laid before the French Institute in 1804, and in which he speaks of similar bodies, without, however, anything special being remarked concerning their basic properties.

Although the discovery of morphia, of meconic acid and their decomposition by heat is shewn to be due to Sertürner, there is some difficulty in determining to whom to ascribe the discovery of narcotine. Derosne had really got the meconate of narcotine from opium and from the product so obtained precipitated the narcotine with alkalies. But the fact is that he had no idea of its true nature and thought it to be a simple body, just as Proust‡ and others before him considered the precipitate obtained from the aqueous solution of opium with alkalies, and as we have seen several chemists long before him had spoken of an opium salt which they had obtained. It depends entirely upon the point of view, when a discovery can be properly said to have been made, but it can hardly be denied that Sertürner is at least to be considered as the *scientific* discoverer of narcotine.

Sertürner's investigations caused a great activity amongst chemists to search for similar basic substances and although in the following years these labours were rewarded with many discoveries, they were less concerned with opium than with the constituents of other plants. Pelletier, Dumas and others were the chief chemists who brought out new results, whilst they completed a number of analyses of organic bodies,§ among them of morphia and narcotine, which in exactness far surpass the earlier analyses of others.‖

It is not until the year 1830 that a new period of discoveries in relation to these bodies commences. Meconine, or opianyl, an indifferent body, was remarked by Dublanc¶ as early as 1826 and was further examined by Couerbe** in 1830. The process employed in practice for the preparation of morphia, that of Robertson and

* *Ann. de Chimie et de Physique*, November, 1818; Gilbert's Ann., 65, 351.
† *Ann. de Chimie*, 92, 225.
‡ *Ann. de Chimie*, 45, 268.
§ *Ann. de Chimie et de Physique*, 24, 163-188.
‖ Thomson, Berzelius, *Jahresbericht*, 1821, 100; Bussy, *ibid.*, 1824, 170.
¶ *Ann. de Chimie et de Physique*, 49, 17.
** *Ibid.*, 49, 44.

Gregory, led Robiquet in 1832 to the discovery of the strong base codeia,* as he observed that the hydrochlorate of morphia obtained by this method, by precipitation with NH_3, yielded less pure morphia than the hydrochlorate obtained by direct precipitation of the aqueous extract of opium with NH_3, *etc.* This caused him to examine the reason of the difference. In the same year, Pelletier† discovered narceine, which he first considered to be a weak base, which view however, he afterwards‡ contradicted. In 1833, Thiboumèry§ discovered thebaine, when attempting to find a new method for the preparation of morphia, in Pelletier's manufactory. This was at first considered by Pelletier as an isomer of morphia, and was therefore called paramorphia, until Couerbe, who recognized its different composition, gave it its present name. In 1848 Merck|| discovered papaverine, another well characterized base.

Besides the bodies already mentioned, others have been discovered in opium. They are, however, either of not much importance, or their very existence is doubtful.

Such are pseudomorphine, opianine, porphyroxine, thebolactic acid, cryptopia and others.

Of much more importance is the labour expended by chemists in the detection of the constitution of these bodies, especially since Liebig (1830) made the analysis of organic substances so extremely simple. But it would occupy too much time even to name all the investigations which have been made and I therefore will only make some remarks on the bases themselves.

How has shewn, that the opium bases are to be regarded as nitril bases. But concerning their constitution we know almost nothing, except narcotine, the separation of which into cotarnine and opianic acid, Wöhler has first shewn. Some time later, Anderson made a further investigation of this subject and found, that the first product of this decomposition is opianyl, and proved the identity of this body with meconine. Afterwards, Matthiessen and Foster's investigation led to the formula for narcotine now in use.

The formula for morphia has been fixed by Laurent. It differs from the formulas employed by Regnault and by Liebig, by having one H less than the former, and one H more than the latter.

* *Journ. de Phar.*, 19, 88.

† *Journ. de Phar.*, 18, 150; *Ann. der Chemie und Physik*, 50, 248, 262.

‡ *Journ. de Phar.*, 21, 574.

§ *Journ. de Chimie méd.*, 1833, 161; *Journ. de Phar.*, 21, 506; *Ann. de Chimie et de Phys.*, 59, 153.

|| *Ann. der Chemie. und Phar.*, 66, 125.

Codeia has been more completely examined by Anderson, who confirms the formula proposed by Gerhardt.

Our knowledge of the composition of thebaine and narceine is due to Anderson. He corrected the error of Pelletier and shewed that narceine is a basic substance.

Merck and Anderson have worked upon papaverine, and the latter confirmed the correctness of Merck's formula and made us acquainted with a number of substitution products.

The formula of meconic acid has been fixed by Liebig and found to be correct by Stenhouse.

Couerbe discovered the composition of meconine, but the formula he employed was doubled by Anderson, one result of his investigations upon narcotine.

The idea that those plants, or portions of plants, which were used in medicine from the earliest times, did not as a whole possess the value ascribed to them, was first promulgated by Paracelsus.* He maintained the presence in them of a proximate principle, which could be extracted and to which the medical action was due; and it was he who tried to separate them and to employ them instead of the entire plant.

This idea of Paracelsus has been since then more or less generally adopted and attempts to realize it have been made.

Accordingly, Derosne instituted physiological experiments † with the body he obtained, and was convinced that he had extracted one of the active constituents of opium. Sertürner also (1817) expressed his opinion ‡ that the medical action of opium was identical with that of pure morphia and that the latter would probably soon expel opium from the pharmacopœia. Somewhat later, when he recognized meconic acid as an active constituent of opium and called it a frightful poison, § he proposed that it and narcotine should be removed from opium before use; || the error however, was first pointed out by Sömering, ¶ after it had been established by Orfila,** Mayer †† and others, that the properties of opium were found to be unchanged in morphia.

Notwithstanding all this, a certain confusion on this point existed during subsequent years and we encounter the striking fact, that while many ‡‡ denied morphia what is now recognized as its char-

* Kopp, *Geschichte der Chemie*, 1, 98. † *Ann. de Chimie*, 45, 282.

‡ Gilbert's *Ann.*, 55, 71, and 85. § Ibid., 57, 183. || Ibid., 57, 187; 59, 69.

¶ Ibid., 65, 387.

** *Ann. de Chimie et de Physique*, 5, 288; Gilbert's *Ann.*, 57, 180.

†† Ibid., 65, 387.

‡‡ Berzelius' *Jahresber.*, 1822, 116; 1823, 169; 1825, 234; 1826, 257.

acteristic effect, capital punishment was at the same time inflicted in France on account of poisoning by its means.

Chemists at that time were no less at a loss for want of a reaction for the detection of morphia in medico-legal cases, as that which had hitherto been used for opium, namely the reaction of meconic acid with a ferric salt, was no longer of any use.

The separation of the really active constituents of opium, and the observation of the extreme variability of its per centage composition, must have convinced physicians, that in this substance they employed an instrument, the powers of which lay beyond their calculation, and must have awakened them to the necessity of substituting for an uncontrolled mixture, a medicine of known action.

From this necessity arose the manufacture on a large scale, of morphia and codeia which has now become so extensive.

The discovery of methods for the separation, on a practical scale, of the constituents of opium, has largely occupied chemists. On the present occasion I shall confine myself to one or two of the most important of these.

The mode of preparation of the two most important opium compounds—morphia and codeia—is the process originally proposed by Robertson and Gregory, the principal points of which are the following:—

From the watery extract of opium, meconic acid is removed by precipitation with $Ca\,Cl_2$ as meconates of calcium, leaving in solution meconine and all the bases, as hydrochlorates. The liquid is then concentrated, whereby it deposits first more meconate of calcium, and afterwards hydrochlorate of morphia and hydrochlorate of codeia. These two bases are separated by $N\,H_3$ which precipitates the morphia, while the codeia remains dissolved.

For the separation of the other ingredients Anderson has given the most convenient mode, which I will describe shortly.

To the mother liquor $N\,H_3$ is added. A precipitate falls, consisting chiefly of narcotine, papaverine and thebaine, while narceine and meconine remain in solution. From this precipitate narcotine is extracted by boiling spirit, the remainder dissolved in water containing acetic acid and papaverine thrown down by subacetate of lead, whereafter it can be extracted from this precipitate by digesting it with alcohol. After the excess of lead in the solution is removed by sulphuretted hydrogen, $N\,H_3$ precipitates thebaine.

If the liquid, containing chiefly narceine and meconine be concentrated, narceine separates, and from the sufficiently concentrated liquid meconine may be obtained by agitation with ether.

The new base, which I have described above, is obtained from the narceine by dissolving it in boiling water.

On account of its behaviour with solvents and with alkalies and alkaline carbonates, I draw the conclusion that it has hitherto been overlooked, although it is probably a constant constituent of opium. I am therefore employed at present in searching for it in the mother liquor from the preparation of morphia and codeia, by the Robertson-Gregory process.

XVI.—*Notes on the Cemetery of Staglieno, near Genoa.* By Mr. Charles Heath Wilson.

Communicated by Dr. Gairdner, March 22, 1871.

Professor Gairdner, in introducing the paper, said that the cause of its being written was that he had heard before of the Cemetery, and on visiting Genoa last May he took the opportunity of going to see it. He had then expressed to Mr. Wilson his desire to have a few details about the Cemetery for the satisfaction of his own mind. Mr. Wilson had been kind enough to send him this long and interesting communication; and he (Dr. Gairdner) thought he should perform a duty by bringing it before the public of Glasgow, more especially because he considered it a solemn obligation, on the part of the public authorities, to take more care for the disposing of the dead than they generally did, or were at present doing, in Glasgow.

Abstract.

Mr. Wilson introduces his subject by contrasting the decent attention now paid to the dead in Italy with the practice formerly existing, of carrying dead bodies, exposed, to the churches where services were performed. The Cemetery of Staglieno, near Genoa, was first proposed in 1835, and the design was approved in 1840. It is the work of the city architect, Professor Rezzasco. Level ground is rare near Genoa; and part of that purchased by the municipality for the cemetery—namely, 60,000 square mètres—was

a rough and rocky hill-side. Excavations were begun, and the soil was cast into the valley at the base to raise it sufficiently above the torrent, and to level it; whilst the hill-side was terraced for the intended buildings. It was a work of considerable labour and expense to excavate so much rock; but in these days of railway cuttings no one shrinks before such attempts. In 1851 the new cemetery was opened, being 250 mètres long and 210 wide; that is, about 812 feet long by about 681 wide. The central level space is surrounded on the front next the torrent, and the two flanks, by magnificent arcaded porticoes, about 18 feet high internally, built of a gray stone, hard and compact, from La Spezzia, and a hard stone of a yellow colour from Nice. The order selected is the Grecian Doric, combined, however, with the Roman arcaded construction; and the general idea of the porticoes is, in point of design, that of a story of the Coliseum, which has served as models for so much Italian architecture. The arches are 8 feet 2 inches in the opening. The width of the arcade from the external line to the internal is 14 feet 8 inches. (The proportions of the structure, and its general appearance, were illustrated by photographs and drawings.) The architectural effect is very noble, the arcades are handsome, and the stair-cases also. The whole of the vast edifice is honeycombed with graves and vaults, the very walls of the arcades in many places containing shelves for bodies. The cost of such a work is great. About one-third remains to be finished; yet already more than a million francs of clear profit has been derived from it by the municipality. Here is an encouragement to municipal virtue and municipal taste. Had it been less splendid, less great as a work of art—had it been a cheese-paring work—the account on the credit side would have been very different. It is its very beauty that makes it so popular that all classes buy graves. The proof which is given of regard for the dead in this new cemetery, the prodigious outlay on graves and monuments, the tender, touching, simple, unaffected inscriptions, altogether tell a tale the very reverse of popular impressions of Italian sentiment and Italian domestic life based on travellers' tales. The lairs are sold at prices which greatly vary, those in the upper galleries being the most costly. The best lairs are sold at 8,000 francs in the upper porticoes, and at 3,000 in those below; that is, at £320 and £120. They are all shallow graves, and contain no earth. The dead, the writer supposes, are buried in lead. The pavements are hermetically sealed. In some cases families have purchased entire divisions, for one of which the Serra family has paid £1,200. The

opposite pavilion will bring 50,000 francs, the desire for possession has so increased. In the back galleries above the wall, graves are 700 francs each; those in pavement, 650 francs, &c. In the central ground a grave can only be purchased for thirty years, at 225 francs. At the end of that time the possession ceases, and the bones are removed to the ossuary and buried permanently. The vaults and shelves in the galleries are permanent property. The writer next adverted to the sculptures introduced into the cemetery, and the great improvement in its style, as contrasted with the state of monumental art, not merely in other countries, but in Genoa itself when the cemetery was founded. Since that period a school of sculpture has been created which produces excellent works. (Photographs of several specimens were shown.) Instances were mentioned of sculpture which cost £880, £640, &c. The cemetery, when finished, including the ground and architectural portion, will cost 5,000,000 francs; but when all the vaults are sold, a large profit will accrue to the municipality. The burial of the poor, in what may be called the "common ground," is done at the expense of the city.

Mr. Bromhead asked if every body was inclosed in a grave hermetically sealed?

Professor Gairdner explained that they were not. The wealthier class were buried in lead coffins, and had no earth on them. The ordinary ones were buried as with us.

Mr. Bromhead having made some remarks on Mr. Wilson's reference to the superiority of the monuments in the Campo Santo,

Mr. Mossman said that if some such scheme as that proposed were carried out in this country, it would put the artists in a much better position. Our northern climate, with its frequent rains, would always be a hindrance to the progress of out-door sculpture; but as our Protestant Church does not encourage to a great extent sculpture within its walls, a system of having decorated cemeteries of this nature would supply a desideratum which in England the fine arts had never enjoyed before. In the Campo Santo in Florence—an open space surrounded by galleries—there was a model which he had often thought would do for this country. The plan described by Mr. Wilson was just the same carried to a further extent. A wealthy community like Glasgow would have no great difficulty, in the course of time, in getting up a very spacious cemetery.

Mr. Downie said that this system was in very general use in some parts of America, especially in the South. The vaults were

bricked up and kept close for a long time before being allowed to be opened again; and in regard to sanitary arrangements, it stood the test. One reason why they did not put earth in the graves at New Orleans was that they were below the Mississippi.

PROFESSOR GAIRDNER said, the only remark he had to make was to strengthen the conclusion to which Mr. Wilson's paper seemed to point,—that in all large places like Glasgow it was a clear duty for the municipality to remove this matter out of the domain of private enterprise, and to deal with it in the large and liberal spirit which it demanded on behalf of the public, both as a matter of taste and æsthetics, and, of what was of far greater consequence, as a matter of decency and public health. In Glasgow our position was as nearly as possible the following:—We had checked the worst abuses to a considerable extent wherever we had the power—only recently, however, we had put an end to the most offensive and abominable pit burials, and had shut up some of the intra-mural cemeteries. But the moment you attempted to go the least thing further, the difficulty was that every single bit of ground they shut up simply raised the price of ground in the extra-mural cemeteries, and increased the difficulty for the poor. Among the 14,000 deaths that took place in the year in Glasgow, a large proportion was among the poor, near the centre of the town; and every difficulty we put in their way was simply making it more impossible for the poor to bury their dead with anything like comfort and decency, and making burial break the back of the poor man. As long as burial was made a matter of private enterprise, we were shutting up the intra-mural cemeteries at the expense of the poor; and there was literally no other way out of it, except for the municipality to constitute themselves the administrators of the whole matter of burial. If we had large numbers of poor living near the centre of the town, it was impossible but that great numbers of deaths must occur there. He held that the municipality should take the matter out of private hands, and liberally assist in the removal of the dead to extra-mural cemeteries. If we removed the cemeteries out of the town for the benefit of the public, the public should repay to the poor man the increase of expense thus caused to him. We could defray the cost of this by the means that the Genoese had used—viz., make the cemeteries so attractive and beautiful that they would pay.

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different and is a decomposition product, and grounds this upon its properties.

In the year 1818, Vauquelin * attempted to obtain the honour of Sertürner's discoveries for France, inasmuch as in 1814 a treatise of Seguin † was in the press, which he had laid before the French Institute in 1804, and in which he speaks of similar bodies, without however, anything special being remarked concerning their basic properties.

Although the discovery of morphia, of meconic acid and their decomposition by heat, is shewn to be due to Sertürner, there is some difficulty in determining to whom to ascribe the discovery of narcotine. Derosne had really got the meconate of narcotine from opium and from the product so obtained precipitated the narcotine with alkalies. But the fact is, that he had no idea of its true nature and thought it to be a simple body, just as Proust ‡ and others before him considered the precipitate obtained from the aqueous solution of opium with alkalies, and as we have seen several chemists long before him had spoken of an opium salt which they had obtained. It depends entirely upon the point of view, when a discovery can be properly said to have been made; but it can hardly be denied, that Sertürner is at least to be considered as the *scientific* discoverer of narcotine.

Sertürner's investigations caused a great activity amongst chemists to search for similar basic substances and although in the following years these labours were rewarded with many discoveries, they were less concerned with opium than with the constituents of other plants. Pelletier, Dumas and others were the chief chemists who brought out new results, whilst they completed a number of analyses of organic bodies,§ among them of morphia and narcotine, which in exactness far surpass the earlier analyses of others.‖

It is not until the year 1830 that a new period of discoveries in relation to these bodies commences. Meconine, or opianyl, an indifferent body, was remarked by Dublanc ¶ as early as 1826 and was further examined by Couerbe ** in 1832. The process employed in practice for the preparation of morphia, that of Robertson and

* *Ann. de Chimie et de Physique.* Novembre, 1818; Gilbert's *Ann.*, 65, 361.

† *Ann. de Chimie*, 92, 225.

‡ *Ann. de Chimie*, 45, 268.

§ *Ann. de Chimie et de Physique*, 24, 153-188.

‖ Thomson, Berzelius, Jahresbericht, 1821, 100; Bussy, *ibid.*, 1824, 170.

¶ *Ann. de Chimie et de Physique*, 49, 17.

** *Ibid.*, 49, 44.

Gregory, led Robiquet in 1832 to the discovery of the strong base codeia,* as he observed that the hydrochlorate of morphia obtained by this method, by precipitation with NH_3, yielded less pure morphia than the hydrochlorate obtained by direct precipitation of the aqueous extract of opium with NH_3, *etc.* This caused him to examine the reason of the difference. In the same year, Pelletier† discovered narceine, which he first considered to be a weak base, which view however, he afterwards‡ contradicted. In 1833, Thiboumèry§ discovered thebaine, when attempting to find a new method for the preparation of morphia, in Pelletier's manufactory. This was at first considered by Pelletier as an isomer of morphia, and was therefore called paramorphia, until Couerbe, who recognized its different composition, gave it its present name. In 1848 Merck|| discovered papaverine, another well characterized base.

Besides the bodies already mentioned, others have been discovered in opium. They are, however, either of not much importance, or their very existence is doubtful.

Such are pseudomorphine, opianine, porphyroxine, thebolactic acid, cryptopia and others.

Of much more importance is the labour expended by chemists in the detection of the constitution of these bodies, especially since Liebig (1830) made the analysis of organic substances so extremely simple. But it would occupy too much time even to name all the investigations which have been made and I therefore will only make some remarks on the bases themselves.

How has shewn, that the opium bases are to be regarded as nitril bases. But concerning their constitution we know almost nothing, except narcotine, the separation of which into cotarnine and opianic acid, Wöhler has first shewn. Some time later, Anderson made a further investigation of this subject and found, that the first product of this decomposition is opianyl, and proved the identity of this body with meconine. Afterwards, Matthiessen and Foster's investigation led to the formula for narcotine now in use.

The formula for morphia has been fixed by Laurent. It differs from the formulas employed by Regnault and by Liebig, by having one H less than the former, and one H more than the latter.

* *Journ. de Phar.*, 19, 88.

† *Journ. de Phar.*, 18, 150; *Ann. der Chemie und Physik*, 50, 248, 262.

‡ *Journ. de Phar.*, 21, 574.

§ *Journ. de Chimie méd.*, 1833, 161; *Journ. de Phar.*, 21, 506; *Ann. de Chimie et de Phys.*, 59, 153.

|| *Ann. der Chemie. und Phar.*, 66, 125.

Codeia has been most completely examined by Anderson, who confirms the formula proposed by Gerhardt.

Our knowledge of the composition of thebaine and narceine is due to Anderson. He corrected the error of Pelletier and shewed that narceine is a basic substance.

Merck and Anderson have worked upon papaverine, and the latter confirmed the correctness of Merck's formula and made us acquainted with a number of substitution products.

The formula of meconic acid has been fixed by Liebig and found to be correct by Stenhouse.

Couerbe discovered the composition of meconine, but the formula he employed was doubled by Anderson, one result of his investigations upon narcotine.

The idea that those plants, or portions of plants, which were used in medicine from the earliest times, did not as a whole possess the value ascribed to them, was first promulgated by Paracelsus.* He maintained the presence in them of a proximate principle, which could be extracted and to which the medical action was due; and it was he who tried to separate them and to employ them instead of the entire plant.

This idea of Paracelsus has been since then more or less generally adopted and attempts to realize it have been made.

Accordingly, Derosne instituted physiological experiments † with the body he obtained, and was convinced that he had extracted one of the active constituents of opium. Sertürner also (1817) expressed his opinion ‡ that the medical action of opium was identical with that of pure morphia and that the latter would probably soon expel opium from the pharmacopœia. Somewhat later, when he recognized meconic acid as an active constituent of opium and called it a frightful poison, § he proposed that it and narcotine should be removed from opium before use; ‖ the error however, was first pointed out by Sömering, ¶ after it had been established by Orfila,** Mayer †† and others, that the properties of opium were found to be unchanged in morphia.

Notwithstanding all this, a certain confusion on this point existed during subsequent years and we encounter the striking fact, that while many ‡‡ denied morphia what is now recognized as its char-

* Kopp, *Geschichte der Chemie*, 1, 98. † *Ann. de Chimie*, 45, 282.
‡ Gilbert's *Ann.*, 55, 71, and 85. § Ibid., 57, 183. ‖ Ibid., 57, 187; 59, 69.
¶ Ibid., 65, 387.
** *Ann. de Chimie et de Physique*, 5, 288; Gilbert's *Ann.*, 57, 180.
†† Ibid., 65, 387.
‡‡ Berzelius' *Jahresber.*, 1822, 116; 1823, 169; 1825, 234; 1826, 257.

acteristic effect, capital punishment was at the same time inflicted in France on account of poisoning by its means.

Chemists at that time were no less at a loss for want of a reaction for the detection of morphia in medico-legal cases, as that which had hitherto been used for opium, namely the reaction of meconic acid with a ferric salt, was no longer of any use.

The separation of the really active constituents of opium, and the observation of the extreme variability of its per centage composition, must have convinced physicians, that in this substance they employed an instrument, the powers of which lay beyond their calculation, and must have awakened them to the necessity of substituting for an uncontrolled mixture, a medicine of known action.

From this necessity arose the manufacture on a large scale, of morphia and codeia which has now become so extensive.

The discovery of methods for the separation, on a practical scale, of the constituents of opium, has largely occupied chemists. On the present occasion I shall confine myself to one or two of the most important of these.

The mode of preparation of the two most important opium compounds—morphia and codeia—is the process originally proposed by Robertson and Gregory, the principal points of which are the following:—

From the watery extract of opium, meconic acid is removed by precipitation with $Ca\,Cl_2$ as meconates of calcium, leaving in solution meconine and all the bases, as hydrochlorates. The liquid is then concentrated, whereby it deposits first more meconate of calcium, and afterwards hydrochlorate of morphia and hydrochlorate of codeia. These two bases are separated by $N\,H_3$ which precipitates the morphia, while the codeia remains dissolved.

For the separation of the other ingredients Anderson has given the most convenient mode, which I will describe shortly.

To the mother liquor $N\,H_3$ is added. A precipitate falls, consisting chiefly of narcotine, papaverine and thebaine, while narceine and meconine remain in solution. From this precipitate narcotine is extracted by boiling spirit, the remainder dissolved in water containing acetic acid and papaverine thrown down by subacetate of lead, whereafter it can be extracted from this precipitate by digesting it with alcohol. After the excess of lead in the solution is removed by sulphuretted hydrogen, $N\,H_3$ precipitates thebaine.

If the liquid, containing chiefly narceine and meconine be concentrated, narceine separates, and from the sufficiently concentrated liquid meconine may be obtained by agitation with ether.

The new base, which I have described above, is obtained from the narceine by dissolving it in boiling water.

On account of its behaviour with solvents and with alkalies and alkaline carbonates, I draw the conclusion that it has hitherto been overlooked, although it is probably a constant constituent of opium. I am therefore employed at present in searching for it in the mother liquor from the preparation of morphia and codeia, by the Robertson-Gregory process.

XVI.—*Notes on the Cemetery of Staglieno, near Genoa.* By Mr. Charles Heath Wilson.

Communicated by Dr. Gairdner, March 22, 1871.

Professor Gairdner, in introducing the paper, said that the cause of its being written was that he had heard before of the Cemetery, and on visiting Genoa last May he took the opportunity of going to see it. He had then expressed to Mr. Wilson his desire to have a few details about the Cemetery for the satisfaction of his own mind. Mr. Wilson had been kind enough to send him this long and interesting communication; and he (Dr. Gairdner) thought he should perform a duty by bringing it before the public of Glasgow, more especially because he considered it a solemn obligation, on the part of the public authorities, to take more care for the disposing of the dead than they generally did, or were at present doing, in Glasgow.

Abstract.

Mr. Wilson introduces his subject by contrasting the decent attention now paid to the dead in Italy with the practice formerly existing, of carrying dead bodies, exposed, to the churches where services were performed. The Cemetery of Staglieno, near Genoa, was first proposed in 1835, and the design was approved in 1840. It is the work of the city architect, Professor Rezzasco. Level ground is rare near Genoa; and part of that purchased by the municipality for the cemetery—namely, 60,000 square mètres—was

a rough and rocky hill-side. Excavations were begun, and the soil was cast into the valley at the base to raise it sufficiently above the torrent, and to level it; whilst the hill-side was terraced for the intended buildings. It was a work of considerable labour and expense to excavate so much rock; but in these days of railway cuttings no one shrinks before such attempts. In 1851 the new cemetery was opened, being 250 mètres long and 210 wide; that is, about 812 feet long by about 681 wide. The central level space is surrounded on the front next the torrent, and the two flanks, by magnificent arcaded porticoes, about 18 feet high internally, built of a gray stone, hard and compact, from La Spezzia, and a hard stone of a yellow colour from Nice. The order selected is the Grecian Doric, combined, however, with the Roman arcaded construction; and the general idea of the porticoes is, in point of design, that of a story of the Coliseum, which has served as models for so much Italian architecture. The arches are 8 feet 2 inches in the opening. The width of the arcade from the external line to the internal is 14 feet 8 inches. (The proportions of the structure, and its general appearance, were illustrated by photographs and drawings.) The architectural effect is very noble, the arcades are handsome, and the stair-cases also. The whole of the vast edifice is honey-combed with graves and vaults, the very walls of the arcades in many places containing shelves for bodies. The cost of such a work is great. About one-third remains to be finished; yet already more than a million francs of clear profit has been derived from it by the municipality. Here is an encouragement to municipal virtue and municipal taste. Had it been less splendid, less great as a work of art—had it been a cheese-paring work—the account on the credit side would have been very different. It is its very beauty that makes it so popular that all classes buy graves. The proof which is given of regard for the dead in this new cemetery, the prodigious outlay on graves and monuments, the tender, touching, simple, unaffected inscriptions, altogether tell a tale the very reverse of popular impressions of Italian sentiment and Italian domestic life based on travellers' tales. The lairs are sold at prices which greatly vary, those in the upper galleries being the most costly. The best lairs are sold at 8,000 francs in the upper porticoes, and at 3,000 in those below; that is, at £320 and £120. They are all shallow graves, and contain no earth. The dead, the writer supposes, are buried in lead. The pavements are hermetically sealed. In some cases families have purchased entire divisions, for one of which the Serra family has paid £1,200. The

opposite pavilion will bring 50,000 francs, the desire for possession has so increased. In the back galleries above the wall, graves are 700 francs each; those in pavement, 650 francs, &c. In the central ground a grave can only be purchased for thirty years, at 225 francs. At the end of that time the possession ceases, and the bones are removed to the ossuary and buried permanently. The vaults and shelves in the galleries are permanent property. The writer next adverted to the sculptures introduced into the cemetery, and the great improvement in its style, as contrasted with the state of monumental art, not merely in other countries, but in Genoa itself when the cemetery was founded. Since that period a school of sculpture has been created which produces excellent works. (Photographs of several specimens were shown.) Instances were mentioned of sculpture which cost £880, £640, &c. The cemetery, when finished, including the ground and architectural portion, will cost 5,000,000 francs; but when all the vaults are sold, a large profit will accrue to the municipality. The burial of the poor, in what may be called the "common ground," is done at the expense of the city.

Mr. Bromhead asked if every body was inclosed in a grave hermetically sealed?

Professor Gairdner explained that they were not. The wealthier class were buried in lead coffins, and had no earth on them. The ordinary ones were buried as with us.

Mr. Bromhead having made some remarks on Mr. Wilson's reference to the superiority of the monuments in the Campo Santo,

Mr. Mossman said that if some such scheme as that proposed were carried out in this country, it would put the artists in a much better position. Our northern climate, with its frequent rains, would always be a hindrance to the progress of out-door sculpture; but as our Protestant Church does not encourage to a great extent sculpture within its walls, a system of having decorated cemeteries of this nature would supply a desideratum which in England the fine arts had never enjoyed before. In the Campo Santo in Florence—an open space surrounded by galleries—there was a model which he had often thought would do for this country. The plan described by Mr. Wilson was just the same carried to a further extent. A wealthy community like Glasgow would have no great difficulty, in the course of time, in getting up a very spacious cemetery.

Mr. Downie said that this system was in very general use in some parts of America, especially in the South. The vaults were

bricked up and kept close for a long time before being allowed to be opened again; and in regard to sanitary arrangements, it stood the test. One reason why they did not put earth in the graves at New Orleans was that they were below the Mississippi.

PROFESSOR GAIRDNER said, the only remark he had to make was to strengthen the conclusion to which Mr. Wilson's paper seemed to point,—that in all large places like Glasgow it was a clear duty for the municipality to remove this matter out of the domain of private enterprise, and to deal with it in the large and liberal spirit which it demanded on behalf of the public, both as a matter of taste and æsthetics, and, of what was of far greater consequence, as a matter of decency and public health. In Glasgow our position was as nearly as possible the following :—We had checked the worst abuses to a considerable extent wherever we had the power—only recently, however, we had put an end to the most offensive and abominable pit burials, and had shut up some of the intra-mural cemeteries. But the moment you attempted to go the least thing further, the difficulty was that every single bit of ground they shut up simply raised the price of ground in the extra-mural cemeteries, and increased the difficulty for the poor. Among the 14,000 deaths that took place in the year in Glasgow, a large proportion was among the poor, near the centre of the town; and every difficulty we put in their way was simply making it more impossible for the poor to bury their dead with anything like comfort and decency, and making burial break the back of the poor man. As long as burial was made a matter of private enterprise, we were shutting up the intra-mural cemeteries at the expense of the poor; and there was literally no other way out of it, except for the municipality to constitute themselves the administrators of the whole matter of burial. If we had large numbers of poor living near the centre of the town, it was impossible but that great numbers of deaths must occur there. He held that the municipality should take the matter out of private hands, and liberally assist in the removal of the dead to extra-mural cemeteries. If we removed the cemeteries out of the town for the benefit of the public, the public should repay to the poor man the increase of expense thus caused to him. We could defray the cost of this by the means that the Genoese had used—viz., make the cemeteries so attractive and beautiful that they would pay.

XVII.—*On some Evidences as to the very Early Use of Iron, and on certain Old Bits of Iron in particular.* By Mr. St. John Vincent Day, C.E., F.R.S.E., &c.

Read before the Society, April 12, 1871.

The object of this paper is to show that a considerably remoter archæology can be claimed for the employment by man of iron than has hitherto been generally accepted. That iron was amongst the very earliest, if not in fact the earliest, of all the metals with which man was acquainted, we have abundant *literary* evidence. Until lately, however, that has stood alone, unconfirmed by any *cotemporary* testimony. Now, however, we are in a position to shew, from two kinds of cotemporary proof, that iron was well known to man, in some parts of this earth at least, during the very remotest ages which it is possible with any degree of certainty to reach. The two kinds of evidence to which I allude are—

1st. That of the hieroglyphs.

2nd. Certain material specimens.

These two evidences appear now not only to confirm each other, but what is more important still, establish the solid truth of that literary testimony which in these latter days has come to be doubted: and although not yet complete, a further confirmation of the extremely ancient uses of iron may confidently be expected ere long as a result of researches into traditions and the comparison of myths,—the inquirers into which having already so well succeeded in evoking little grains of truth out of whole mountains of myth.

When examining the works of those authors who have written on the history of iron, I have frequently noticed the scantiness of their attempts to indicate what is until now absolutely ascertained, as distinct from what is handed down as tradition concerning the use of that metal in pre-historic ages; and I am disposed to believe that defect merely as a result of the trust which those authors appear to have placed in the teachings of a certain modern school, which, going dead against all literary testimony, declares for, and only for, the extremely high antiquity of copper and its alloys. When, too, certain researchers into the "Antiquity of Man"—supposing him to have been evolved by successive spontaneous efforts from an extremely low type of organic existence—claim that the appearance of iron

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on the scene marks so decided a step on the road to a higher civilization, it is strange, indeed, that their inquiries into the remotest limit of time, when man became an iron-using animal, bear no stamp upon them indicative of having been directed into the earliest ages of which, and in countries where, we have positive cotemporary testimony—actual cotemporary fact to rest upon—rather than that a continued trust should be vouchsafed to the very uncertain records and theories as concerning other countries and still later ages, but founded only on mere probabilities.

Writers on what has hitherto been defined as the early history of iron we have had in abundance, since the time when Layard deposited in our British Museum the metallurgical trophies of his excavations in that Interamnian plain where once stood the Assyrian Nineveh and Babylon; or since Rhind, after exploring the tomb of Sebau, wherein he is reported to have discovered, "on the massive doors of the inner repositories, hasps and nails, still as lustrous and as pliant as on the day they left the forge,"* contended that iron was extensively used in Greece between the epoch of the Homeric poems (from 900 B.C. to 1000 B.C.) and the full historic period of Greece, and that within about the same interval, if not probably with an earlier commencement, the same metal was more or less completely displacing bronze in Egypt. It is inferred by Rhind—at least so I gather from Dr Percy's remarks—that Sebau was born about B.C. 68, and died B.C. 9; but we shall hereafter see that iron was known to and used by the Egyptians many centuries earlier, also that, before the time of the Persian invasion under Cambyses, there was enough iron in the country, as Belzoni has pointed out, to make instruments of agriculture with. Plate I. is a full-sized picture of a sickle † found by Belzoni under

* *Metallurgy: Iron and Steel.* By John Percy, F.R.S. London. 1864.

† Extract from *Narrative of the Operations and Recent Discoveries within the Pyramids, Temples, Tombs, and Excavations in Egypt and Nubia, etc., etc.* By G. BELZONI. A.D. 1821. Published by Murray.

"Two other articles were found in this excavation, of which one is a tombstone, and the other *an iron sickle*" (p. 162). . . . .

"But the iron sickle, to which I would call the attention, was found under the feet of one of the sphinxes on its removal. I was present; one of the men took it up and gave it to me. It was broken into three pieces, and so decayed that the rust had eaten even to the centre. It was rather thicker than the sickles of the present time, but exactly of the common shape and size of ours. It is now in the possession of Mr. Salt. The question is, At what time were these statues placed there? They could not have been deposited subsequently to the age of the Ptolemies; for it appears that since the time of Cambyses, who

the feet of one of the sphinxes at Karnak,—a sufficient proof that, at about B.C. 600, the blacksmith's art was well understood and practised in Upper Egypt; so that whilst the testimony I hope to adduce may be no refutation of Rhind's view in regard to iron displacing bronze at the particular time he mentions—for it is quite within the limits of probability that when alloys were discovered iron may have for a time fallen into disuse—yet the evidence to be hereafter dealt with will, I venture to believe, shew that to Egypt, and not Greece, must our attention be addressed for the solution of all problems bearing on the most ancient metallurgy.

By the distinguished leader in another branch of modern investigation the true history of iron has had a thick veil cast over it. I allude to what Professor Max Müller, who, reasoning on a purely philological basis, has propounded; but on examining his great work, the *Science of Language*, it is easy to see that he has been largely influenced by M. Morlot's conclusions, for he quotes M. Morlot extensively; and from the use of certain words in the *Odyssey*, concludes that the Greek language was spoken before the discovery of iron, and that iron certainly was not known previous to the breaking up of the Aryan family. But Professor Max Müller has overlooked apparently what may be gathered as to the early use of iron from another great branch of the human family—namely, the Semitic—to which branch both modern Coptic and ancient Egyptian belong, as indeed he himself has pointed out.* The testimony of the ancient Egyptian language, as well as modern Coptic, have of late thrown a flood of light on the subject of this inquiry. Yet, before passing on from Professor Max Müller, I wish to bring to your notice—for I should err in my duty were I to omit doing so—another still more remarkable error into which he has fallen, by trusting it would seem, too exclusively to language-science. This error occurs in the following sentence:—"In the Homeric poems, knives, spear-points, and armour were still made

destroyed the gods of Egypt, the country has never been invaded, so as to compel the people to conceal their idols; and it is evident that these statues had been hidden in a hurry, from the irregular and confused manner in which they lie. Now, as the sickle was found under the statue above mentioned, I think it a sufficient proof *that there was iron in the country long before the invasion of the Persians*, since the Egyptians had enough to make instruments of agriculture with. Sickles of the same form are to be seen in many agricultural representations in the tombs," etc., etc. (p. 163).

* *Lectures on the Science of Language* (p. 316). London, 1866. First Series. Longmans.

of copper; and we can hardly doubt that the ancients knew a process of hardening that pliant metal, ***most likely by repeated smelting and immersion in water.****

Now, what exactly the phrase "repeated smelting" may mean, as used in this connection, it is difficult to assert; but as *smelting* involves *heating*, I conclude that the phrase should rather be "repeated heating." But whether I am correct in that inference is of no consequence; for, as a pure matter of certainty, it is well known that, unlike iron, copper is *not hardened* by immersion or cooling in water, but, on the contrary, it is *softened* thereby; indeed, it is the constant practice of coppersmiths and other craftsmen, when desiring to soften that metal or its alloys, to heat it and cool it in water, whilst it is hardened by rolling, beating, or pressing; and one of these latter operations was doubtless not unknown to the Greek makers of knives and spear-heads in copper.

The paucity of researches bearing on the knowledge and use of iron in pre-historic ages can, as I have already hinted at, be scarcely any other than the direct outcome of that dogma propounded by the Danish and Swedish antiquaries—Nillson, Steenstrup, Forchammer, Worsaäe, and others—which teaches that men began to use tools of stone, then bronze, and lastly iron.

As to the beginnings of man, in *some* parts of the world at least, to do his work with stones, it is no business of ours just now to enter upon, nor, indeed, does there seem occasion to do so, for the conclusions in that connection appear, so far as an incomplete testimony can go, well founded. But concerning the further question, as to whether bronze and iron came *universally* to be employed in the order of succession assigned to them by the progressive developists, amongst each of the sections of mankind now grouped according to the character of their language into the Aryan, Semitic, and Turanian families, we have, I believe, sufficient grounds to question.

It is asserted, as I have already mentioned, that the appearance of iron on the scene is an index to certain guides of our own times, that a higher civilization prevailed than where bronze is present, as may be gathered from the following passage of Sir Charles Lyell's writings, when quoting M. Morlot,† he says:—"The next stage of improvement that is manifested by the substitution of

* *Lectures on the Science of Language* (p. 230). London, 1868. Second Series. Longmans.

† *Bulletin de la Société Vaudoise des Sciences Naturelles*, tom. vi., p. 292.

iron for bronze indicates another stride in the progress of the art. Iron never presents itself except in meteorites in a native state; so that to recognize its ores, and then to separate the metal from the matrix, demands no small exercise of the power of observation and invention."* To the metallurgist, however, who is conversant with the art and science of extracting metals from the ores, and of compounding them together as alloys, the picture at once presents a different view; and it is indeed some satisfaction to know that the bronze and iron order of succession does not receive the assent of our leading living metallurgist, Dr. Percy.

That school, however, which claims the higher antiquity for the alloy bronze seems to infer that because no iron specimens are pointed out so old by centuries, perhaps by thousands of years, as this spear-head, that chisel, this bowl, or that hatchet (and I am not aware that any one has yet proved that an iron specimen has been found in the whole world which could be pronounced even so old, not to mention older, than any one of the many bronze relics of which such a legion exist; indeed, when we reflect upon a certain peculiarity inherent to the metal iron, and, for our present considerations, practically absent from the alloy bronze, it does appear scarcely possible that a specimen of metallic iron should be found belonging to nearly so early an age as that to which even tolerably late bronze specimens belong; for we need only to be reminded that iron, when exposed to the action of the air or moisture, even in a very few years, becomes converted into an oxyde, and so entirely that it is often not possible to recognize whether it had previously been reduced to the metallic condition or not), iron could not have been previously used.

The Proto-Egyptian remains, monuments, etc., in Lower Egypt are allowed by all men of all creeds to be the oldest extant relics of the works of the human race, (some of them not only the most stupendous, but the most perfect in mechanical excellence that we can ascertain to have at any time been erected on this earth, and but for which inherent quality they would long since have passed out of the reach of our eye-witness—as many others of a lower order of mechanical construction, and of far later date, have passed away, even so that their place can nowhere now be found), and confronting these primeval structures with the bronze and iron succession dogma, as educed more especially from Scandinavian philosophy—how does the dogma fit the facts before us

* *The Geological Evidences of the Antiquity of Man, &c.*, by Sir Charles Lyell, Bart., F.R.S. London, 1863.

in respect of Proto-Egyptian testimony. Methinks I hear the supporters of that dogma re-echo, "Exactly;" "for bronze, it has been said, was compounded of such proportions of the two metals that the resulting alloy was so hard that it would cut stone just as well as the steel chisels and jumpers of to-day; and therefore it must have been used in those extremely early erections." This is, however, I am disposed to believe, rather a begging of the question, and specially illogical. For we may surely in all fairness ask, that since bronze is so slowly oxidizable, if it really was used in Lower Egypt, on these the very earliest works of man on the earth, should we not find some specimens of it in or about these said monuments? Yet, so far as I have been able to ascertain, *not a single relic* has been found throughout the whole Nile valley which can *with certainty be pronounced so old as either the material or hieroglyphic testimony which we now possess regarding iron.*

But, to turn again to the question of the priority of iron, how does the investigation result? Not, as we should expect, from the bronze and iron succession doctrine, but precisely the reverse of that; for not only are iron instruments depicted in the tomb pictures of the 4th dynasty at Memphis, but at Memphis itself: among the monuments there metallic iron has been found, and is now in this country of ours. Not only is metallic iron found in that very locality to-day, but remarkably so, it has been found in the very oldest building of all there—by universal accord the very oldest building in the whole earth; not in that particular building either, in such a way as to have been placed there by accident or intention, at a time subsequent to the erection, but in such a way that it could have been placed there when and only when the structure was in course of erection. Now, it may perhaps appear startling to be told that, after a lump of malleable iron was removed by blasting it out from the solid masonry of the Great Pyramid by Col. Howard Vyse, thirty-five years ago, and which has been ever since deposited in the British Museum, I have altogether failed to meet with an allusion to it by any writer on the history of metallurgy. This piece of iron to which I refer was not dug up amongst any rubbish or concreted mass of matter at the foundations of the Pyramid which have there accumulated, but near the top of the building, as the following passage and certificates, quoted from Howard Vyse's *Pyramids of Gizeh*, testify.

"Mr. Hill discovered a piece of iron in an *inner* joint, near the mouth of the southern air-channel, which is probably the oldest

piece of wrought iron known.* It has been sent to the British Museum, with the following certificates:"—

"This is to certify, that the piece of iron found by me near the mouth of the air-passage in the southern side of the Great Pyramid at Gizeh, on Friday, May 26th, was taken out by me from an *inner* joint, *after having removed, by blasting, the two outer tiers of the stones* of the present surface of the Pyramid; and that *no joint or opening of any sort was connected with the above-mentioned joint*, by which the iron could have been placed in it after the original building of the Pyramid. I also shewed the exact spot to Mr. Perring on Saturday, June 24th.

"J. R. HILL.

"CAIRO, *June 25th*, 1837."

"To the above certificate of Mr. Hill I can add, that since I saw the spot at the commencement of the blasting, there have been two tiers of stones removed, and that if the piece of iron was found in the joint pointed out to me by Mr. Hill, and which was covered by a large stone, partly remaining, *it is impossible it could have been placed there since the building of the Pyramid.*

"J. S. PERRING, C.E.

"CAIRO, *June 27th*, 1837."

"We hereby certify that we examined the place whence the iron in question was taken by Mr. Hill, and we are of opinion *that the iron must have been left in the joint during the building of the Pyramid, and that it could not have been inserted afterwards.*

"ED. S. ANDREWS.
JAMES MASH, C.E."

"The mouth of this air-channel had not been forced—it measured $8\frac{7}{8}$ inches wide by $9\frac{1}{8}$ inches high—and had been effectually screened from the sands of the desert by a projecting stone above it."

Since, then, the Great Pyramid is absolutely the oldest building on every testimony, both that of Herodotus, the hieroglyphs, and astronomy, as proven by the researches of Lepsius, Wilkinson, Fergusson, Herschel, and Smyth; and whereas iron is found there and bronze is not; and whereas it is doubtful whether any bronze relics found near Jeezeh are so old as the Pyramid, I think the proof is clear to the most obstinate, that for iron we must claim an antiquity far higher than that hitherto assigned to it. Yet some will doubtless object to such a conclusion, seeing that it is only a single specimen which, so far, has been found. It must not, however, be forgotten that had not this specimen been in the

* Lord Prudhoe is said to have brought from Egypt an ancient iron instrument; and I thought that I had perceived the remains of an iron fastening in the chamber containing the sideboard or shelf in the great temple at Abou Simbal. In fact, *stone could not have been quarried without metal, which must, therefore, have been in use in the earliest times.* The smelting of metals seems to have been an antediluvian art.

position which the certificates I have read to you point out, that is, walled in, removed from contact with the corroding action of the atmosphere and moisture, but in an exposed position, even it could not have come down to our day; so that if, as doubtless there may have been, numerous tools of iron, or perhaps, nay, almost certainly, steel left in that locality by the Pyramid builders, it is certain that unless enclosed, as the specimen under notice was, not one of them would have lasted until now, even in that driest of climates—Lower Egypt.

Before, however, we do, from the evidence afforded by this particular specimen of iron from the Great Pyramid, commit ourselves to certainly assigning it to be of cotemporary date with that monument's erection, we have, in order to act fairly towards all parties, to ask ourselves whether it is not probable that it may have been surreptitiously dropped into the place by some wily Arab worker, just after the stones surrounding its site were blasted away—for some persons will doubtless be found sceptical on that head—when remembering the cunning with which modern Arabs are reported to drop fragments of pottery and burnt brick into Nile mud excavations, on purpose to find them afterwards, so as to entitle them to baksheesh from the exploring parties. If this Pyramid piece of iron had been found so recently as the times when the Nile mud excavations were carried on, wherein Arab sagacity was evoked to practical wrong-doing in the prospect of reward, I for one should be disposed to place little trust indeed in its testimony; but whereas it was removed from the Pyramid some twenty years before the time when Hekekyan Bey and Mr. Leonard Horner began sinking pits and boring in the Delta, and in whose day it would appear that the Arab trick was developed; and whereas the finding of metallic specimens in the Pyramid was no part of Howard Vyse's inquiry, as the finding of pottery specimens in the Delta was of the later investigators,—it does not look in any way reasonable to suppose that the iron found its way there so surreptitiously; and as a positive argument against the validity of that suggestion, the very condition of the piece of iron itself may be noticed, as shewn by figs. 1 and 2, Plate II.*—namely,

* This Plate, as well as Plate I., show the iron specimens full size, and have been copied from photographs specially prepared to illustrate this paper.

My friend, W. Petrie, has been kind enough to spend much time, at my request, in the examination of this piece of iron from the Great Pyramid; and in writing me lately regarding it, he says,—"Thickness originally, probably $\frac{1}{4}$ inch. In some parts it is now $\frac{1}{8}$, including the scale of rust, and in other parts it thins off to nothing. The side having the label upon it is much

the fact of its having pieces of nummulite limestone—indeed, the trace of a nummulite itself—of which very stone the Pyramid is built, still adhering to it; and this condition of the piece of iron certainly looks like valid evidence of its having been built into the Pyramid, and therefore cotemporary with the erection of that monument. Yet we still require evidence from other sources to ratify our conclusions, and which is happily forthcoming. But, before speaking of that further evidence, I wish to consider another matter.

It is asserted by many persons now-a-days, who, it would appear, are but little versed in metallurgic science, that iron indicates a further acquaintance with metallurgic art than bronze indicates. This, I believe, is a conclusion not only erroneous, but one which no practical metallurgist would assent to. Looking broadly at the face of metallurgic science, it is scarcely possible to point out a simpler and more readily occurring result, than the reduction of iron ores to the metallic condition, in the manner wherein that was effected prior to the modern invention of cast iron. We must remember that there is not a tissue of evidence that cast iron was known to the ancients, although certain writers, and amongst them a well known member of this Society, Mr. James Napier, has written, that the *reduction* of iron ore is performed by mixing the oxide of the metal "with coal or other carbonaceous matters, and subjecting them to a heat of sufficient intensity *to fuse them*."* Now, it is well ascertained, as the result of a very long experience, that iron may be reduced from the oxides to the metallic state without fusion; indeed, in the most perfect blast furnace operations, the iron is reduced by carbonic oxide before the charge reaches that portion of the furnace where fusion takes place (the smelting zone of Scheerer). When fusion does take place, we get from the

rougher than the other side; and on this side is a trace of a nummulite, in lighter colour than the iron, concreted on it; and there is also a nodule of stone, ½ inch diameter, projecting from the surface, and sinking into the rusty mass. Judging from general appearances and weight, not more than half of what now remains of it consists of rust, the remainder is probably yet metallic. The colour of the rust is the usual dark-brown or blackish, not reddish; and it is a very hard and solid kind of rust, like the magnetic iron ore. It has evidently been flexible, tough wrought-iron."

* *Ancient Workers and Artificers in Metal.* By James Napier, F.C.S., &c. London, 1856. P. 132.

And Sir Charles Lyell, as if borrowing his information from Mr. Napier, goes somewhat farther, when he writes—"To *fuse* the ore requires an intense heat, not to be obtained without artificial appliances, such as pipes inflated by *the human breath*, or bellows, or some other suitable machinery."

furnace either cast iron or crude steel, the iron being combined with a portion of the carbon of the charge. From what we know of the most ancient methods of reduction, the *fusion* of the metal was by them impossible. Hence the attempts in modern times to extol the difficulty of iron-making, by supposing its fusion to have been necessary, and therefore raising it high above the state of knowledge requisite for the more complex operations of forming an alloy out of two dissimilar metals, are not only incorrect but extremely misleading. The same author, to whom I have already referred, even goes so far as to say that "the smelting and manufacture of iron is surrounded with so many difficulties, and needs so many requirements and such skill, that we would expect it to have been amongst the last of the metals that were brought into use." Now, from what has been said, and from what follows, it will, I believe, be admitted that not only is iron the very first metal which we should expect to find brought into use, merely on account of the simplicity by which it is reduced from its ores—namely, by heating the oxides in contact with carbon, and maintaining that contact for a length of time sufficient to allow the carbon, by a process analogous to that of cementation, to attack the oxygen to the innermost parts of the lumps of ore, resulting finally in a mass of malleable iron or a crude steel, ready to be re-heated and hammered into any shape desired. Whilst I have been thus led to point out the tendency towards erroneous conclusions to which Sir Charles Lyell and Mr. Napier have helped us, yet I must, in due courtesy, acknowledge that the latter gentleman upsets his own conclusions by showing, from literary and monumental proof, that the use of iron was at least coeval with bronze, if not anterior to it; and in so far he has helped much those who reason from the metallurgist's point of view; for, quoting Sir Gardner Wilkinson, Mr. Napier says:—"Iron and copper mines are found in the Egyptian desert, which were worked in old times; and the monuments of Thebes, and some of the towns about Memphis, dating more than 4,000 years ago, represent butchers sharpening their knives on a round bar of metal attached to their aprons, which, from its blue colour, can only be steel."*

Sir Gardner Wilkinson himself, too, as late as 1847, when the third edition of his famous five volume work† was published, has written—"The most remote point to which we can see opens with a nation

* "*The Ancient Workers in Metal*" (p. 133). London, 1856.

† "*The Manners and Customs of the Ancient Egyptians,*" p. viii., Preface. London, 1847.

possessing all the arts of civilized life already matured." Which passage contrasts strikingly with another in the same volume (p. 59),—"It was about the same period, B.C. 1406, that some suppose the use of iron* to have been first discovered in Greece; but whether it was already known in Egypt or no, is a question hitherto unanswered. We are surprised at the execution of hieroglyphics cut in hard granite and basaltic stone, to the depth of two inches, and naturally enquire, what means were employed—what tools were used? If the art of tempering steel was unknown to them, how much more must our wonder increase? and the difficulty of imagining any mode of applying copper to this purpose adds to our perplexity." It is singular that so faithful and fair-dealing an author as Sir Gardner Wilkinson, one, too, so pre-eminently versed, after his long residence in Egypt, as to the facts relating to its history, and writing, too, so many years after the deposit of the Great Pyramid iron specimen in the British Museum, and being in general so exact a scholar in the hieroglyphs, should assert that "whether iron was already known in Egypt *or no, is a question hitherto unanswered.*" Since, however, Wilkinson, Lyell, Morlot, and certain Swedes and Danes have published their views to the world, Egyptilogical research has not stood still; on the contrary, it has been prosecuted with continued energy, resulting, so far as our present purpose is concerned, with some striking corroborations of the use of iron, not only so early as the Great Pyramid age, but much earlier still; for we find, as it has been so learnedly set forth by Mr. Basil H. Cooper,† that there is well ascertained hieroglyphic evidence of iron being known in Egypt even so early as the sixth or seventh monarch of the *first* dynasty.

Mr. Cooper says,—"It must, I think, be conceded . . . that supposing iron to have been known to the Egyptians . . . its employment in the construction of those Titanic erections, the Pyramids, . . . is far more probable than the hypothesis that none but bronze tools were used. And this, I venture to think, can be satisfactorily demonstrated.

"The proof is based on the extremely significant Coptic word for iron, as illustrated and explained by the mode in which it is written

* "Hesiod (in his Opera et Dies) makes the use of iron a much later discovery. In Theseus' time, who ascended the throne of Athens in 1235 B.C., iron is conjectured not to have been known, as he was found buried with a brass sword and spear. Homer generally speaks of brass arms, though he mentions iron."

† *Trans. Devonshire Association for the Advancement of Science, Literature, and Arts.* 1868.

in the hieroglyphical inscriptions, and on the occurrence of that word as a component element in the name of an Egyptian Pharaoh belonging to the first dynasty. The modern Egyptian word for iron is, in the Sahidic dialect, which is considered to be the purest Benipi, or, with a slight change in the final vowel, Benipe. In the hieroglyphical form of the language it is the same. . . . Its first element is BA or BE (in the Coptic BO), meaning 'hard-wood,' or 'stone;' and the two letters which spell the word are often accompanied in the hieroglyphical inscriptions by a picture of the squared stone, such as those of which the pyramids were built. At other times, as if to remind us that the word originally meant 'hard-wood,' and that it was only in process of time that it came to denote 'hardware' in general, including such stone hardware as was going in very early times, the picture illustrating the spelt word was a branch or sprig. The middle syllable in the word Benipe consists of the letters NI, with a very short vowel. It is a preposition, answering to the English 'of.' The last element in the composite word is the syllable PE, which is the Coptic word for heaven, or the sky. And that this is really its signification here is proved incontrovertibly by the pictures with which this syllable is wont to be accompanied in the hieroglyphical orthography of the word Benipe; for it is the picture invariably used to denote the heaven, or the sky, and is employed for no other purpose. Properly, it represents the ceiling of a temple, which was regarded as itself a representation of the sky, the true ceiling of the true and original temple; and the picture is accordingly wont to be emblazoned with stars. Hence," says Mr. Cooper, "the signification of the entire word Benipe, . . . although it could not for some time be conceived why the Egyptians should have called iron by so singular a name as 'stone of heaven,' 'stone of the sky,' 'sky-stone.'"

Some time afterwards, however, it occurred to me that this was the very name which would naturally be given to the only iron with which men were likely to meet in a natural state. There is but one exception to the rule that iron is never found native, like gold and some other of the metals; that exception is in the instance of *meteoric iron*, which might surely be called with propriety "the stone of heaven, or of the sky." "Moreover—and I have to thank my friend Mr. Pengelly for reminding me of the fact, and so materially helping me to shape out my crude speculation—meteoric iron needs no preparatory process, as does that procured from ores, to render it workable. In short, we may be sure, especially with the light thrown on the matter by this invaluable Egyptian word,

bright with the radiance of that heaven which enters into its composition, that with this wondrous matter from another sphere than our own the working of iron began."

Whether Mr. Basil Cooper be right or not in his final conclusion, that meteoric iron was the first used, I think we scarcely have sufficient evidence to convince us, although it looks extremely probable; but that the hieroglyphic testimony is at one with all the other evidence, no one, I should suppose, would now dispute; and especially when we find that in Lower Egypt, in the very earliest times, the inhabitants worked so perfectly in granite, diorite, and others of the very hardest stones, for which copper or bronze tools would be useless, the result of all the testimony which I have adduced is to add another link to the completion of that chain of evidence which in Egypt pre-eminently proves the extremely high intellectuality of man in the earliest ages which we are able, with certainty, to fathom.

In conclusion, I have to record my obligations to the Directors of the British Museum; and especially to the keeper there of the Oriental Antiquities, the learned Dr. Birch, for affording me the opportunity of having photographed, under Dr. Birch's superintendence, the specimens of iron referred to in this communication; and to my friend Mr. W. Petrie I am much indebted for frequent visits to the British Museum, and for personally applying to the Directors, and procuring their permission to photograph the iron relics.

MINUTES.

Corporation Buildings, November 2, 1870.

THE Sixty-ninth Session of the Philosophical Society of Glasgow was opened this evening, in the East Hall of the Upper Corporation Galleries—DR. BRYCE, the President, in the Chair.

The following gentlemen were elected members, having been nominated at the closing meeting of last session, viz.:—

Mr. Stephen Mason, Manufacturer, 47 Queen Street; Mr. Allan H. Maclellan, 6 Lansdowne Crescent; Mr. C. Buie Renshaw, Glenpatrick, by Paisley; Dr. William Greenlees, 11 Elmbank Street; Mr. Thomas Wilkinson Watson, 8 Grafton Place; Mr. John Rankine, Manager, Strathclyde Turkey-red Dye Works; Dr. A. Wood Smith, F.F.P.S.G., 5 Newton Terrace; Mr. James A. Wenley (Bank of Scotland), 8 Lynedoch Crescent; Mr. J. C. Wyper (Messrs. F. Orr & Sons), Union Street; Mr. Robert A. Bryden, I.A., 34 Abbotsford Place; Mr. William Melvin, 89 South Portland Street; Dr. James Stewart, 6 Brandon Place; Mr. Alexander Fergusson, Treasurer, Caledonian Railway Company, 31 Elmbank Crescent; Mr. James Aspin, Varnish Manufacturer, 1 India Street, West; Mr. Archibald Nairn, Wright, 24 Cochran Street.

The PRESIDENT delivered the Annual Address, for which, on the motion of DR. YOUNG, he received the thanks of the Society.

It was agreed to request two of the three following gentlemen to audit the Treasurer's Accounts,—viz., Mr. Thomas Nicolson, Writer; Mr. James Reid, Union Bank; and Mr. William Ramsay, C.E.

Corporation Buildings, November 16, 1870.

The Society met this evening for the Sixty-ninth Annual Election of Office-bearers, and for other general business—DR. BRYCE, the President, in the Chair.

The following were elected members, viz.:—

Dr. Charles Cameron, A.M., 294 Bath Street; Dr. T. E. Thorpe, Professor of Chemistry, Anderson's University; Mr. James Napier, Jun., Chemist, 21 Roslin Drive, Dennistoun; Mr. John Struthers, Manager, Turkey-red Dye Works, Blantyre; Mr. Kenneth M. Macleod, Sanitary Inspector for the City, 5 Richmond Street; Mr. Robert Lockhart, 158 St. George's Road; Dr. William F. Collier, 12 Belmont Crescent; Mr. Andrew Hunter, 274 Bath Street; Mr. William Stevenson, 4 Berkeley Terrace.

Mr. William Keddie, the Secretary, read the Council's Report on the State of the Society,—which was approved of, and ordered to be printed in the *Proceedings*.

Report by the Council on the State of the Society.

I. *Accommodation.*—At the date of last Annual Report, negotiations were in progress between the Council and the Galleries Committee, with a view to obtaining suitable accommodation for the ordinary meetings of the Society, the capacity of the Lecture Hall having been found insufficient for this purpose. The difficulty was at length overcome by the Committee offering to the Society, for its ordinary meetings, the East Hall of the Upper Corporation Galleries, at an additional rent of £30 per annum; which offer the Society, especially in consideration of the large influx of new members, authorized the Council to accept; and which it accordingly did, in terms of the following missive:—

"The Council of the Philosophical Society of Glasgow hereby offers to the Galleries Committee of the Town Council to lease the East Hall of the Corporation Galleries, for the usual general meetings of the Society, at a rental of £30 sterling per annum, on condition that the Hall is put into a suitable and comfortable state, by adequate means being adopted to prevent draughts from the roof and doorways; the Society at the same time to abide by the former arrangement with the Galleries Committee as to the occupation of the Library Hall throughout the year, and the use of the Lecture Hall for Sectional Meetings on Mondays and Wednesdays, from the month of November to May inclusive, at a rental of £100, including £50 of annual interest accruing to the Society from the Exhibition Fund in possession of the Town Council; said lease to last for the period of ten years, from November, 1869, to November, 1879, with a break, at the option of either party, at the end of five years."

II. *Architectural Section.*—The Council of the Glasgow Architectural Society having concluded an arrangement for a union of that body with the Philosophical Society, as one of its Sections, the formation of the Architectural Section was declared on the 12th of January. The number of members of the Section, who are also members of the Philosophical Society, is 47. They have brought into the Society a large and valuable collection of books on architecture, which remain their own property, but are freely accessible to all the members of the Society. This collection occupies a separate room. A catalogue of the books will be appended to the Society's Library Catalogue, now in the press.

III. *The Proceedings.*—The printed *Proceedings* of the Society in the Session 1869-70 occupied 358 pages, and form the second part of the Seventh Volume.

The opening address, by Dr. Bryce, the President, contained a comprehensive account of the life and labours of the late Mr. Thomas Graham, Master of the Mint, together with notices of deceased members of the Society. Sixty pages are occupied by a condensed report of a discussion on the subject of Patents for Inventions, which occupied three successive meetings of the Society, and gave rise to very general interest. This was followed by a paper "On the Principles Affecting the Solvency of a Life Assurance Company, and the best means of Protecting the Public against their Violation," by Mr. James R. Macfadyen. Dr. W. T. Gairdner, Professor of Practice of Physic in the University of Glasgow, and Health Officer of the City, delivered a discourse "On defects of House Construction in Glasgow as a cause of Mortality," which gave rise to a discussion occupying a separate evening, and which is also reported in the *Proceedings.* Mr. Watson, the City Chamberlain, read a paper "On the Vital and Social Statistics of Glasgow in 1869." Mr. John M. Thomson made a communication "On the Appearance and Chemical Constitution of Ancient Glass found in Tombs in the Island of Cyprus." Dr. Bryce read a paper "On the Syenitic Rocks of Westfield, near Linlithgow, with remarks on the suitability of various rocks for harbour works and street materials." This was followed by a paper "On China Grass," by Mr. W. Keddie.

To the Chemical Section the *Proceedings* were indebted for the following communications, viz.:—"Note on the Action of House Sewage on Lead Pipes," by Mr. Edward C. C. Stanford; "On the Estimation of Iodine and Bromine, with special reference to the Analysis of Kelp," by Mr. Robert R. Tatlock; "On the Chemistry

of Coal Smoke," by Mr. W. R. Hutton; "On Artificial Alizarine," by Mr. J. Wallace Young; "Notes of Experiments on Artificial Alizarine," by Mr. John Christie; "Note on a specimen of Shell Sand from the Island of Coll," by Mr. Edward C. C. Stanford; "On a Method for Obtaining a Continuous Current of Air in Gas under Pressure, for Blow-pipe or other Purposes," by Mr. T. L. Patterson; "On the Examination of Air," by Dr. R. Angus Smith.

Papers on the following subjects were read before the Society, but not included in the printed *Proceedings*—viz., "On the Geological Structure of Skye and the West Highlands," by Dr. Bryce; "On the Recent Progress of the Iron Manufacture in Cleveland," by Mr. John Mayer; "On the Definition of a *Formation* in Geology," by Professor Young; "Description of the Structural Characteristics of the different species of Megalichthys, with microscopical illustrations," by Mr. James Thomson.

The *Proceedings* close with a report on the business of the Chemical Section, by Mr. Tatlock, the Secretary; and a report from the Sanitary and Social Economy Section, by Mr. David G. Hooy, the Secretary, containing a *résumé* of an important succession of papers and discussions, which, during the session, had occupied the attention of the Section.

State of the Membership.—In last annual report it was stated that the total membership on the evening corresponding to the present was 387, the increase on the previous year having been the greatest ever reported in any one session. On the present occasion the Council has to report that this rate of increase was greatly exceeded during the last session, the total number of members now on the roll, including nine elected this evening, being 507.

Mr. St. John Vincent Day, the Librarian, read a Report on the State of the Library,—which was approved of, and ordered to be printed in the *Proceedings*.

Report of Librarian on the State of the Library.

On taking office, the Library Committee found the work of furnishing the Library hall, and of arranging the Library in its new abode, as well as the system of exchanges, necessarily incomplete; but they are now glad in being able to state that the furnishing of the Library hall is completed,—a series of reading tables and chairs have been provided, and the floor has been covered with Kamptulicon. Another matter of great importance has been carried

out—namely this, that all the book-cases have been labelled with alphabetical marks, and the books arranged in the cases so as to effect a maximum of economy in the space at our disposal.

By means of these case or press marks, the knowing where to find any and every book in the collection will be in the possession of every member,—that particular knowledge will be now removed from the control of the sub-librarian; but to prevent any irregularities, such as have sometimes occurred, the book-cases will for the future be kept locked. Hitherto the catalogue consisted merely of an alphabetical and classified list of the books, but no one except the sub-librarian knew where to find a book when it was asked for; and, at any time of change in the appointment to that office, great confusion and inconvenience were necessarily caused to the members. That defect will now be entirely removed, as in the new catalogue a special mark will be appended to each entry, indicating the case or press and shelf therein where the book or books are to be found. The new catalogue is in the printer's hands; but its accuracy depends on one condition, which the Library Committee cannot too earnestly impress upon all those members who at present have books in their possession,—namely, that they return all books to the library at once, in order that the titles and other particulars may be duly mentioned in, and compared with, the new catalogue. Unless this matter is attended to, it is next to impossible to make the catalogue as perfect as we desire it to be.

In the purchasing of new books, the Library Committee have endeavoured to provide such works in science which appear to be the requisites of a strictly "Philosophical" library, excluding such works as may be found in the more *general* libraries of a large city like Glasgow. The Library Committee wish, however, to mention the desirability of more frequent use of the "proposal" book than has hitherto been practised. Nearly two hundred volumes have been added to your library during the last year, besides books received as donations, as well as the usual purchase of periodic scientific literature. Amongst the volumes added, the Library Committee are glad to notify a complete copy of the *Philosophical Transactions* from the commencement of the Royal Society, down to the present year—in all, eighty-seven volumes. You will be pleased to hear that this set of the *Philosophical Transactions*—a most difficult work to obtain, except at an enormous price—has been procured at an exceedingly low price, barely over ten shillings per volume. Besides works in our own language, the Committee endeavoured to provide the leading scientific works in other

European languages, as well as to make up defects of volumes in works incompleted.

But the strife on the Continent has for the time put an end to scientific publishing there; it has affected, too, the publishing world generally, insomuch that very few works of importance to a "Philosophical" library have made, or are likely to make their appearance this season. The system of exchange which your late librarian so greatly enhanced has been extended. Your librarian has lately placed himself in communication with many other bodies hitherto, it is believed, unapproached, and so far with success. But, gentlemen, there is one great misfortune with which we have to contend,—the library itself is driven into a corner,—we have not room enough, our book-cases are crammed; and, as you know, we now have an addition—viz., the library of the Architects' Society—but very unsatisfactorily provided for; for it cannot be said that where these valuable books are now located, in a cramped committee-room, is a fit place for them; more accommodation for our books we must have, if the Society continues to grow at the present rate; and unless a proposal which it is hoped ere long to notify for that purpose is carried out, it is to be feared a complaint may come from our Architectural Section.

In binding, several arrears have been made up, but a great many more works remain to be bound. Your library is rapidly growing—it now numbers over five thousand volumes; and what I ask, whilst you vest the office of librarian in my hands, is, that you will aid me with your advice and suggestions, so as to enhance its efficiency.

MR. JOHN MANN, the Treasurer, gave in an Abstract of Treasurer's Account for Session 1869-70, duly audited,—which, having been printed in the Society's circular calling the present meeting, was held as read, and was adopted.

ABSTRACT OF TREASURER'S ACCOUNT. SESSION 1869-70.

DR.

1869.—*Nov. 1.*		
To Balances forward—		
In Union Bank of Scotland, ...	£0 16 7	
In Treasurer's hands, ...	0 11 10½	
		£1 8 5½
Carry forward, ...		£1 8 5½

Brought forward,				£1	8	5½
1870.—*Oct. 31.*						
To Entry Money and Dues from 88 New Members, at 42*s.*,				£184	16	0
,, Annual Dues from 4 Original Members, at 5*s.*,	1	0	0			
,, Annual Dues from 1 Original, for two years,	0	10	0			
,, Annual Dues from 314 Members, at 21*s.*,	329	14	0			
,, Annual Dues from 16 Members, for two years,	33	12	0			
,, Annual Dues from 3 Members, for three years,	9	9	0			
				374	5	0
,, Subscriptions towards Expense of Furnishing New Rooms,				8	6	6
,, Chemical Section.—From 43 Associates, at 5*s.*,	£10	15	0			
Balance of Dinner Fund,	1	1	6			
	11	16	6			
Minus Expenses of Section,	2	4	4			
				9	12	2
,, Sanitary Section.—From 8 Associates, at 5*s.*,	2	0	0			
Minus Expenses of Section,	0	18	11			
				1	1	1
,, Architectural Section.—From 49 Members, at 21*s.*,	51	9	0			
Minus Expenses,	2	9	0			
				49	0	0
,, Interest from Bank,				0	12	0
,, Corporation of Glasgow.—Interest on "Exhibition Fund,"				25	11	4
,, Balance due Treasurer,				41	1	5½
				£695	14	0

Cr.

1870.—*Oct.* 31.						
By Salaries and Wages,				£125	0	0
,, New Books and Binding,	£211	12	7			
,, Printing *Proceedings*, Circulars, &c.,	165	6	0			
,, Delivery and Postage of Circulars,	37	14	6			
,, Diplomas and Stationery,	8	1	0			
				422	14	1
,, Rents and Taxes,	£88	4	0			
,, Fire Insurance, Gas, Coal, Cleaning, &c.,	20	5	5			
,, Advertising, Petty Charges, and Sundries,	12	5	7			
				120	15	0
,, Subscriptions to Societies, &c.—						
Ray Society, 1870,	£1	1	0			
Committee of British Association on Sewage,	5	5	0			
Fund for the Family of Professor Sars of Christiania,	5	0	0			
				11	6	0
,, Furniture for Rooms,				14	6	6
,, Balance in Union Bank,				1	12	5
				£695	14	0

Glasgow, *11th November, 1870.*—We, the Auditors appointed at a Meeting of the Society, held on 2nd instant, have examined the Treasurer's Accounts, of

which the above is an Abstract, and found them correct, the Balance in Union Bank, at 31st October last, being One pound twelve shillings and fivepence; and due to the Treasurer, Forty-one pounds one shilling and fivepence halfpenny Sterling.

The Treasurer has also exhibited to us a Voucher which he holds for money lent to the Corporation of Glasgow, from proceeds of Exhibition in 1846, amounting, with Interest to 15th May last, to £1,180, 9*s.* 4*d.*, such interest having, however, been received by the Society as from 26th October, 1869, in terms of arrangement with the Corporation for Rent.

(Signed) JAMES REID.
WILLIAM RAMSAY.

The Society then proceeded to the annual election of Office-bearers.

On the motion of the President, Professor Sir William Thomson, LL.D., was elected by acclamation to the office of Vice-President, vacant by the death of Dr. Francis H. Thomson.

On the motion of the President, carried by acclamation, Mr. St. John Vincent Day was re-elected Librarian; Mr. John Mann was re-elected Treasurer; and Mr. William Keddie was re-elected Secretary.

A ballot was then taken for the election of Four Members of Council to fill the places vacated by the retiring, in rotation, of Mr. George Anderson, M.P., Mr. Alexander Herschel, Professor Young, and Mr. John Downie, when the following gentlemen were elected, viz.:—Dr. William Wallace, Mr. Horatio K. Bromhead, Mr. James Anderson, Mr. William R. W. Smith.

Mr. George Watson and Mr. Archibald Robertson were appointed to scrutinize the votes.

In the interval between the ballot and the scrutiny of votes, Mr. James R. Napier exhibited and described Stevenson's Ship Lamp.

Office-bearers of Philosophical Society for 1870-71.

President.

James Bryce, M.A., LL.D., F.G.S.

Vice-Presidents.

Professor Allen Thomson, M.D., F.R.S.

Professor Sir William Thomson, LL.D., F.R.S.

Librarian.

Mr. St. John Vincent Day, C.E., F.R.S.E.

Treasurer.

MR. JOHN MANN, C.A.

Secretary.

MR. WILLIAM KEDDIE, F.R.S.E.

Other Members of Council.

MR. WILLIAM MACADAM.
MR. EDWARD C. C. STANFORD, F.C.S.
MR. MOSES PROVAN, C.A.
MR. SIGISMUND SCHUMAN.
DR. J. G. FLEMING.
MR. JAMES NAPIER, F.C.S.
MR. DANIEL MACNEE, R.S.A.
MR. ROBERT GRAY.
MR. WILLIAM R. W. SMITH.
MR. JAMES ANDERSON.
MR. HORATIO K. BROMHEAD, I.A.
DR. WM. WALLACE, F.R.S.E., F.C.S.

Corporation Buildings, November 30, 1870.—*The* PRESIDENT *in the Chair.*

Mr. Adam White, Mr. Thomas Colquhoun, Mr. D. M'Arthur, and Mr. Nathaniel Dunlop, were elected members of the Society.

MR. JAMES NAPIER, Sen., read a paper, entitled, "The Farmer and the Chemist."

MR. JAMES R. NAPIER exhibited and described a Directional Rain Guage of his own contrivance.

On the recommendation of MR. JAMES R. NAPIER, it was remitted to the Council to consider the propriety of printing and circulating the *Proceedings* in Parts, including the Discussions, as soon as possible after the papers have been read before the Society.

Corporation Buildings, December 14, 1870.—*The* PRESIDENT *in the Chair.*

SIR WILLIAM THOMSON, LL.D., made a communication "On the Attractions and Repulsions due to Vibration, observed by Guthrie and Schellbach."

Corporation Buildings, January 11, 1871.—DR. ALLEN THOMSON, *Vice-President, in the Chair.*

The following were elected members, viz.:—

Mr. W. P. Ellison, Inspector of Cleansing, 23 St. Enoch Square;

Mr. Thomas D. Smellie, Surveyor and Property Agent, 209 St. Vincent Street; Mr. William Neilson, Writer, 307 St. Vincent Street.

Dr. Bryce read a paper "On the Question as between Sir Roderick I. Murchison and Professor James Nicol, in regard to the Age of the Rocks of the Central Highlands."

Corporation Buildings, January 25, 1871.—*The* President *in the Chair.*

The following were elected members, viz.:—

Mr. William Jones, Civil Engineer, Caledonian Railway Engineers' Office; Mr. John William Douie, Cashier, 23 West Nile Street; Mr. John Anderson, Secretary, 48 Dundas Street; Mr. George W. Jaffrey, The Firs, Partick; Mr. Siegmund Wulff, Dun Allan, Partick Hill; Mr. Gustav Jacoby, Merchant, Prospect Hill Villa, Montgomery Road; Mr. William M'Ewan, 148 Bothwell Street.

Professor Herschel and Professor Thorpe gave "An Account of some of the Scientific Results and Experiences of the late Expeditions for Observing the Solar Eclipse."

Professor Grant added some remarks on the same subject.

Corporation Buildings, February 8, 1871.—*The* President *in the Chair.*

The following were elected members:—

Mr. A. Buchanan Dick, Merchant, 79 Hill Street, Garnet Hill; Mr. Alexander D. Dean, Engraver, 105 Hill Street, Garnet Hill; Mr. William J. Armstrong, Iron Merchant, 3 Royal Exchange Court; Mr. Alexander Scott, 19 St. Vincent Crescent.

Professor Herschel read a paper "On Helmholtz's Analysis of the Vowel Sounds," which was illustrated by experiments.

Corporation Buildings, February 22, 1871.—*The* President *in the Chair.*

Mr. James L. Selkirk, Accountant, and Dr. Labone, Professor of Languages, were elected members.

Mr. James R. Macfadyen, Fellow of the Faculty of Actuaries in Scotland, read a paper entitled, "The Theory of the Death Rate, with Measurements of the Comparative Force of Mortality in Glasgow and other Cities."

The reading of the paper was followed by a discussion, in which Bailie Morrison, Mr. Osborn, Dr. Fergus, Mr. Wm. R. W. Smith, Mr. Mayer, Mr. Macadam, Mr. Collins, Mr. Mactear, Mr. Schuman, Mr. Dunlop, Dr. Lyon, &c., took part.

Corporation Buildings, March 8, 1871.—*The* President *in the Chair.*

Mr. Robert Knox Masterton and Mr. George Hamilton were elected members.

On the motion of Mr. John Mayer, seconded by Mr. James R. Napier, it was remitted to the Council to report on the terms upon which those members have been admitted who have been proposed at or near the close of the Session, and elected at the beginning of the next.

The President called attention to the loss which the Society and the Council have sustained by the recent death of Mr. Moses Provan; and proposed that it be remitted to the Council to prepare a Minute in regard to his death, to be engrossed in the Minute-book, and a copy transmitted to Mr. Provan's widow. The proposal was agreed to.

It was moved by the President, seconded by Dr. Young, and resolved, That the Society be authorized to co-operate with the Senatus of the University, and other public bodies, in inviting the British Association to revisit Glasgow at an early period.

The Rev. Henry W. Crosskey, of Birmingham, read a paper "On Scientific Education in National Elementary Schools."

In the discussion which followed, Mr. James R. Napier, Professor Young, Mr. John Mayer, and Mr. Jeffray took part; and on the motion of Mr. J. R. Napier, the following were appointed a Committee to watch over the interests of Science teaching, in so far as these are involved in the Education Bill for Scotland—viz., The President, Dr. Young, Sir William Thomson, Mr. Teacher, Mr. Mayer, Mr. William M'Adam, Mr. George Anderson, M.P., and Mr. James R. Napier—the latter gentleman being appointed Convener, and the Committee empowered to add to their number.

The Rev. Henry W. Crosskey then read a paper "On the Relationship of the Post-tertiary Beds of England to those of Scotland."

Corporation Buildings, March 22, 1871.—*The* President *in the Chair.*

The Council reported, in regard to the remit of last meeting, on the motion of Mr. Mayer, seconded by Mr. J. R. Napier, that no change should be made in the rule for the admission of members, in its application to those who may be proposed at the last meeting of a Session, and elected at the first meeting of the next Session.

The Council proposed that the following Obituary Notice of the late Mr. Moses Provan be engrossed in the Minutes—which was agreed to by the Society; and the Secretary was instructed to communicate a copy of the same to Mrs. Provan:—

"The Philosophical Society of Glasgow record their sincere sorrow for the loss they have sustained by the death of Moses Provan, Esq. of Auchengillen, who had long been a Member of the Society, and for nearly three years a Member of the Council.

"Mr. Provan's pursuits were literary rather than scientific. He excelled as a linguist. He was one of the founders, and an active and liberal promoter, of the Glasgow Athenæum. But he not the less evinced a warm and intelligent interest in the proceedings of this Society. On his being chosen a Member of Council, he addressed himself to the discharge of his duties with an obvious desire to advance the prosperity and usefulness of the Society. He attended the meetings of Council with regularity, and was present at the last meeting held before his death. His deportment was invariably marked by a high sense of honour; and his courtesy and gentlemanly feeling won for him the confidence and consideration of those associated with him in the management of the Society.

"In communicating to Mrs. Provan, as they do with the most respectful sympathy, this expression of their esteem for the memory of her lamented husband, they beg at the same time to offer her their sentiments of sincere condolence on the sudden termination of a union so recently formed, with every prospect, to human view, of prolonged and unalloyed happiness."

Mr. James Thomson, F.G.S., read a paper "On the Discovery of Fragments and Boulders of Granite in Schistose Rocks in Islay."

Professor Gairdner, M.D., read "Notes on the Cemetery of Staglieno, near Genoa, its Architecture and Monuments," by Mr. Charles Heath Wilson.

Corporation Buildings, April 12, 1871.—*The* President *in the Chair.*

Mr. James Dickson was elected a member.

On the motion of the President, Mr. William R. W. Smith was appointed Convener of the Committee on Patents for Inventions, in room of Mr. Walter Montgomerie Neilson, who has resigned that office.

A paper was read by Mr. St. John Vincent Day, "On some of the Evidences as to the Knowledge and Use of Iron in pre-historic Ages, and on certain bits of Iron in particular."

Mr. Robert R. Tatlock read the "Annual Report on Proceedings of the Chemical Section," for which he received a vote of thanks.

Report from Chemical Section.

The Council of the Chemical Section have much pleasure in being able to report to the Society that the Section is now in a much more prosperous condition, both as regards membership and the amount of work accomplished, than at any former period of its history.

The Associates who are not members of the Philosophical Society are seventy-six in number. The number of meetings that have been held during the past Session is ten, at which sixteen papers have been read. Many of these were the result of much patient labour and investigation, and were of an entirely original character.

At the opening meeting of the Session, held on the evening of the 7th November, Mr. Alex. Whitelaw, Vice-President, in the absence of the President, delivered the Introductory Address, in which he referred at great length to the progress of Chemical Science during the last few years, and to the life and labours of distinguished chemists recently deceased.

At the following meeting, held for the transaction of business, Dr. Wallace was unanimously appointed President for three years, Dr. Anderson's term of office having expired.

On the evening of the 5th December, Dr. Wallace read a paper "On the Impurities and Illuminating Power of Coal Gas," in which

he explained the methods most commonly in use for determining the illuminating power and impurities present, and illustrated the descriptions with the apparatus used in actual practice.

At the next meeting, MR. R. R. TATLOCK read a paper "On some Sources of Error in Volumetric Analysis," in which he called attention to the circumstance of error arising from the contraction of saline solutions when mixed with water.

At the meeting held on 16th January, DR. CLARK read a paper "On Peroxide of Hydrogen or Hydroxyl." The author referred principally to the double character of the oxygen atom, and illustrated the subject with numerous beautiful experiments of a kind seldom exhibited in the lecture-room.

On the evening of 30th January, MR. JOHN SUTHERLAND read a paper "On the Pumping of Hot Liquids." The improvement in the pump he described consisted in allowing a jet of cold water spray to fall into the upper part of the horizontal pipe, which condensed the steam and restored the vacuum. On the same evening, MR. E. C. C. STANFORD read three papers, entitled respectively, "On Fulmar Oil from St. Kilda," "On Tyree Marbles," and "On the Retention of Organic Nitrogen by Charcoal."

At the following meeting, MR. ALEX. S. HERSCHEL read a paper "On the Results of the Discussions on the recent Eclipse Expedition." This was followed by one from PROFESSOR DEWAR, of Edinburgh, "On the Relation of Heat to Chemical Re-actions." This was an exceedingly interesting as well as valuable paper, and of a class well suited to the requirements of the Section. It was succeeded by one from MR. J. W. YOUNG, "On the Analysis of an Alkaline Spring from Cathkin, near Rutherglen,"—the peculiarity of the water being, that it contained about 17 grs. per gallon of soda in the form of bicarbonate, only small quantities of lime and magnesia, and no sulphates.

At the meeting of 13th March, DR. THORPE read a paper "On the Chemical Constitution of Paraffine." He stated that, by distillation under pressure, he had succeeded in breaking up paraffine into liquid hydrocarbon entirely. This paper was succeeded by one "On Artificial Alizarine," by MR. J. WALLACE YOUNG, in which he stated that the results of his experiments led him to the conclusion that the artificial alizarine manufactured from coal tar was identical with the natural alizarine of madder root.

At the next meeting, MR. JOHN FERGUSON read a paper "On some recent Criticisms of Lavoisier." He traced the career of that chemist minutely, and stated that he believed him to be no dis-

coverer, but acknowledged his ability to make inferences from the discoveries of others.

At the same meeting, Mr. James Stark read a note "On the Analyses of Intestinal Calculi, and an Earthball from the Horse;" after which, a very able paper "On the Re-actions of some of the Opium Bases, and on a new Opium Base," by Mr. L. Meyer, was read. This paper was the product of many months' investigation and labour, which had been rewarded by the discovery of a new alkaloid in opium, to which the author had not yet been able to give a name.

At the closing meeting of the Session, Dr. Stevenson Macadam, of Edinburgh, will read a paper "On the Photogenic Power of Oils."

Mr. David G. Hoey read the "Annual Report on Proceedings of the Sanitary and Social Economy Section," for which he received a vote of thanks.

A recommendation to the Society, in the latter Report, to petition Parliament on certain points in the Education Bill for Scotland, was fallen from, with the consent of several office-bearers and members of the Sanitary and Social Economy Section now present.

Report from Sanitary and Social Economy Section.

The business of the Section has been carried on during the present Session with considerable spirit and energy; and, whilst due attention has been given to the subject to which the Section may be said to owe its origin—viz., the Sewage Question—several other highly important sanitary and social questions have likewise been brought up for consideration and discussion.

At the commencement of the Session the Council made arrangements for obtaining papers from gentlemen well qualified to speak upon various aspects of a considerable number of questions, embracing the following:—

1. The Sewage Question.
2. Improved Houses for the Poorer Classes.
3. The Education Question.
4. The Liquor Traffic.
5. Loan Societies and Club Tickets.

And all of these have been taken up, with the exception of the last, which remains over for consideration next Session.

The papers read during the Session have been the following, viz.:—

1. "On the Sewage Question, with special reference to the late Reports of the River Pollution Commission, and the British Association Committee," by Mr. E. C. C. Stanford, F.C.S.

This paper was of a most exhaustive and able nature, and was illustrated by numerous specimens. It has since been printed and published at the request of the Section.

2. "On various aspects of the Sewage Question," by Councillor Ure.

3. "A Critique on Mr. Corfield's recent Report on the Sewage Question," by Mr. Gavin Chapman.

4. "On the Operations of a Society, established in Jarrow, for enabling the workmen of the Palmer Shipbuilding Company to provide themselves with suitable Dwellings," by Mr. John M'Intyre.

The above paper was read by the Secretary, who, at the same meeting, exhibited and explained a model in wood, prepared by Mr. Thomas Hoey, illustrative of his scheme for improved dwellings for the poorer classes.

5. "On the Liquor Traffic: its exceptional character and treatment," by Mr. J. L. Selkirk.

This paper was an argument in favour of the policy of the Permissive Bill Association—that Association having requested, and been accorded, an evening for the advocacy of their views.

6. "On the Social, Economical, Financial, and Commercial results of the conversion of 70,000,000 bushels (or thereby) of grain per annum into intoxicating liquors by Brewing and Distillation in Great Britain and Ireland," by Mr. Wm. Melvin.

7. "On a National System of Education: What it means, and What it involves," by the Rev. J. Page Hopps.

8. "On the Scottish Education Bill: its merits and its defects," by Mr. Stephen Mason.

The papers submitted had been prepared with ability and care, and brought out the views of the writers with great force and clearness. Interesting and lively discussions followed in every case.

With the exception hereinafter mentioned, no definite resolutions or conclusions were arrived at on any of the questions under consideration. On the subject of the Sewage, nothing was advanced to alter the former finding of the Section.

On the question of improved houses for the poorer classes, no definite indication of opinion was elicited, beyond that of the imperative necessity of some improvement being effected.

On the Liquor Traffic, the discussions were unavoidably one-sided, the representatives of the traffic having entirely absented themselves from the debates, in marked contrast to the energy and zeal they displayed in the previous Session, and the opinions expressed by the general members having been strongly in favour of some measure of restriction.

On the Education Question, it was resolved that the Section recommend the parent Society to petition Parliament—

1st. For the insertion of a compulsory clause in the Scottish Education Bill.

2d. That no grants of public money be given to denominations after the passing of the bill, regard being had to existing life interests.

3d. That no catechism or religious formularies be taught in the National Schools. The addition of the words, "except in the hours specified in the conscience clause," was moved, but negatived by a majority.

4th. That the Bill should contain a time-table conscience clause, to regulate the hours at which the Bible may be read, either before or after the ordinary school hours.

5th. That the Bill be amended by the substitution of £50 for £35 as the minimum salary of the teachers.

6th. The compulsory exclusion of ecclesiastical and theological qualifications as conditions of the teacher's engagement; and afterwards the exclusion of theological subjects as subjects to be taught by him.

The previous question was moved, but the motion was carried by a majority.

The attendance at the various meetings of the Section averaged from twenty-five to thirty. Unlike the other Sections of the Society, we have no large body belonging to any special business or profession on whom to rely for attendance, but must, on the contrary, depend solely on the interest taken in questions of a general kind. Still, we are of opinion that a much larger attendance of the members of the Philosophical Society might reasonably be expected, in view of the importance of the subjects discussed at our meetings, and of the ability which the readers of papers have shown, and the labour they have spent in their preparation. On this point the Section is of opinion that greater interest might be excited by its existence and proceedings being kept more prominently before the members of the parent Society; and to this end the Council of the

Section respectfully ask that the President of the Society should, at the close of each fortnightly meeting of said Society, intimate the next meeting of this Section and the paper to be then brought up.

Corporation Buildings, April 19, 1871.—*The* PRESIDENT *in the Chair.*

PROFESSOR SIR WILLIAM THOMSON, LL.D., made a communication on "Experimental Illustrations of the Dynamical Theory of Ships' Rolling." Sir William also exhibited and described "New Forms of Permanent Daniell's Batteries."

The PRESIDENT then intimated that this was the closing meeting of the Session.

INDEX.

PAGE

Air, Current of, for Blow-pipe purposes, 323
Air, Examination of, 326
Alizarine, Artificial, 316
——— ——— Experiments on, 318
Architectural Section, Formation of, 343

Bald, J. H., and James Mactear, on Salt Deposits of Stassfurt, 67
Bateman and Bazalgette, Report on Sewage and Purification of the Clyde, 16
Bessemer Converter, Flame of, 41
Bryce, Dr., on Syenitic Rocks, 293

Cemeteries, Discussion on, 474
Cemetery of Staglieno, 472
Chemical Section, Reports of, 126, 351, 501
China Grass or Rheea, 296
Chloride of Zinc, Action upon Morphia, 459
Christie, J., Experiments on Artificial Alizarine, 318
Coal Fields of England, 64
Coal-smoke, Chemistry of, 313
Crosskey, H. W., on Post-tertiary Geology, 92
——— on Science Education, 446

Day, St. John V., on Evidences of the Early Use of Iron, 476
——— on Sun's Distance and Parallax, 77
Death-rate, Discussion on, 439
——— Theory of, 425
Dynamite, 11

Earthball and Intestinal Calculi, Analyses of, 456
Eclipse of the Sun, Observations in Spain, 405
Eclipse of the Sun, Observations in Sicily, 413
Eclipse Observations, Discussion on, 415

PAGE

Education, Scientific, in National Schools, 446
Eozoon Canadense, Notices of, 118, 381

Farmer and Chemist, 387

Gairdner, Dr. W. T., on Defects of House Construction, 245
Geology of Scotland. Post-tertiary, 92
Glass, Ancient, Chemical Constitution of, 288
Graham, Thomas, Master of the Mint, Obituary Notice of, 137
Grant, Prof. on the Physical Constitution of the Sun, 103

Hamilton, Dr. Mathie, Obituary Notice of, 153
Herschel, A. S., on Eclipse of the Sun, 405
——— on Helmholtz's Analysis of Vowel Sounds, 417
——— on Spectrum Analysis, 39
House Construction in Glasgow, 245, 258
House Sewage, its Action on Lead Pipes, 307
Hull, Edward, on the Coal Fields of England, 64
Hutton, W. R., on Coal-smoke, 313
——— on Igniting Point of Vapours, 49

Iodine and Bromine, Extinction of, 308
Iron, Evidences of its Early Uses, 476

Keddie, W., on China Grass, 297

Life Assurance, 221
Light for Ships, Stevenson's, 386
Liquor Ammoniæ from Glasgow Sewage, 119

Macfadyen, Jas. R., on Life Assurance, 221
——— on Theory of Death-rate, 425

PAGE
Mayer, E. L., on Morphia, &c.,... 459
Minutes of Society,................ 113, 331, 489
Morphia, Action of Acids upon,... 459

Napier, J. R., on Stevenson's Light for Ships,................ 386
——— on a Rain Gauge,........................ 398
Napier, Jas., Sen., on the Farmer and the Chemist,................ 387

Opium-base, a New,................ 459

Paraffin, Chemical Constitution of, 454
Patents for Inventions, Discussion on,................................ 158
Patterson, T. L., on Air Current for Blow-pipe,.................... 323
Pavonaria quadrangularis, Notice of,.................................. 119
Penny, Dr. Frederick, Obituary Notice of,.......................... 364
Petroleum as Fuel,................ 12
President's (Dr. F. H. Thomson) Opening Address,................ 1
President's (Dr. Bryce) Opening Address,............................ 137
President's (Dr. Bryce) Opening Address,............................ 359

Rain-gauge, Wind-direction,....... 398
Ransome's Concrete,................ 9
Robertson, Dr. George, Obituary Notice of,.......................... 157
Robson, Neil, Obituary Notice of, 156
Rowan, T., on Flame of Bessemer Converter,.......................... 41

Salt Deposits, at Stassfurt,......... 67
Sanitary and Social Economy Section formed,.................... 123, 127
Sanitary and Social Economy Section, Reports of,.............. 127, 353, 503
Science Education, Discussion on, 450
Science, Progress of,................ 571
Sewage of Glasgow, Bateman and Bazalgette on,.................... 16
Sewage Question, a Chemist's View of,.............................. 53
Sewage, Utilization of,............ 14
Shell Sand from Coll,................ 323
Smith, Dr. R. Angus, on Air,..... 326

PAGE
Spectrum Analysis,.................. 38
Stanford, Edward C. C., on Action of House Sewage,................ 307
——— on Sewage,................................ 53
——— on Shell Sand,................................ 323
Stark, J. F., Analyses of Earthball, &c.,................................ 456
State of the Society, Council's Reports on,........................ 115, 332, 490
State of the Library, Reports on, 336, 492
Statistics, Vital and Social, of Glasgow,............................ 262
Sugar Manufacture, Chemistry of, 22
Sun's Distance and Parallax,...... 76
Sun, Physical Constitution of the, 103
Syenitic Rocks of Westfield,....... 293

Tall's Method of Building,......... 6
Tatlock, R. R., on Estimation of Iodine and Bromine,.............. 308
——— on Volumetric Analysis,................................ 442
Thomson, Dr. F. H., Obituary Notice of,.............................. 359
Thomson, John M., on Ancient Glass from Cyprus,................ 288
Thomson, Sir W., on Maintenance of Solar Heat,.................... 111
——— on Attractions and Repulsions due to Vibration, 401
Thorpe, Dr., on Eclipse of the Sun, 413
——— on Paraffin,............ 454

Ure, John, Obituary Notice of,... 157

Vibration, Attraction and Repulsion due to,.......................... 401
Volumetric Analysis, Sources of Error in,.............................. 442
Vowel Sounds, Helmholtz's Analysis of,................................ 417

Wallace, Dr. W., on Sugar Manufacture,................................ 22
Watson, W. West, on Vital and Social Statistics,.................. 262
Wilson, C. H., on Cemetery of Staglieno,.............................. 472

Young, J. W., on Artificial Alizarine,.............................. 316

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ERRATA.

In page 197, second line from top, *for* "jacquard," *read* Giffard.
In page 379, tenth line from top, *for* "1,000,000," *read* 1,000,000,000.
In page 399, first line, *for* "observations," *read* observatories.